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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 120.
L. O. HOWARD, Entomologist and Chief of Bureau.

REPORT OF A TRIP TO INDIA AND THE ORIENT IN SEARCH OF THE NATURAL ENEMIES OF THE CITRUS WHITE FLY.

U. S. DEPT. OF AGRICULTURE
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BY
RUSSELL S. WOGLUM,
Entomological Assistant.

ISSUED FEBRUARY 28, 1913.

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BUREAU OF ENTOMOLOGY.

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J. G. Sanders, *collaborator.*

LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Entomology,
Washington, D. C., September 11, 1912.

Sir: I have the honor to transmit herewith an account of the trip undertaken by Mr. Russell S. Woglum, a special agent of this bureau, to India and the Orient in search of the natural enemies of the citrus white fly, which for many years has militated against the successful commercial operation of the orange-growing industry in Florida and elsewhere. This paper is especially valuable in view of the fact that Mr. Woglum not only has located many of the natural enemies of the citrus white fly in their native habitat, but has, as well, demonstrated the correct methods of procedure in the transshipping, alive, of predaceous and parasitic material, which has heretofore rendered the importation of natural enemies of our insect pests so precarious. I recommend the publication of this manuscript as Bulletin No. 120 of this bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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REPORT OF A TRIP TO INDIA AND THE ORIENT IN SEARCH OF THE NATURAL ENEMIES OF THE CITRUS WHITE FLY.

INTRODUCTION.

This bulletin has been prepared with the idea of presenting some of the more important phases, from a scientific standpoint, of a journey made in search of parasitic and predatory enemies of the citrus white fly (*Aleyrodes citri* R. and H.). The major portion of the bulletin is devoted to a treatment of material bearing directly on the citrus white fly, its enemies in Asiatic countries, and the efforts toward their collection and introduction into the United States. Supplementary to this is appended a consideration of other topics with which the writer became familiarized during the expedition and which have a more or less direct bearing on the culture of citrus fruits.

The information herein relative to life history, distribution, and injury of the white fly in this country has been taken largely from the results of the work of Drs. Morrill and Back in their investigations of the citrus white fly in Florida.[1]

THE CITRUS WHITE FLY.

General.

The citrus white fly belongs to a group of insects popularly known as the mealy-wings (Aleyrodidæ) and is closely related to the scale insects (Coccidæ), numerous species of which are very injurious to citrus fruit trees in all parts of the world. In fact, entomologists of the earlier days classified the Aleyrodidæ as a division of the Coccidæ. Subsequent investigators, however, have found certain characteristics normal to the group sufficiently distinct to call for its separation into a family of its own.

The first record of the white fly as a serious pest to citrus fruit trees was from the State of Florida, and from the date of that record to the present time its injury has continued as a menace to the most profitable commercial citrus-fruit production. In 1885 the insect was given the scientific name of *Aleyrodes citri* by Mr. Wm. H. Ashmead[2] in a local Florida paper and subsequently was fully described by Riley and Howard, of the Division of Entomology, in Insect Life.[3]

[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.
[2] Florida Dispatch, n. ser., vol. 11, November, 1885.
[3] Ins. Life, vol. 5, no. 4, pp. 219–226, 1893.

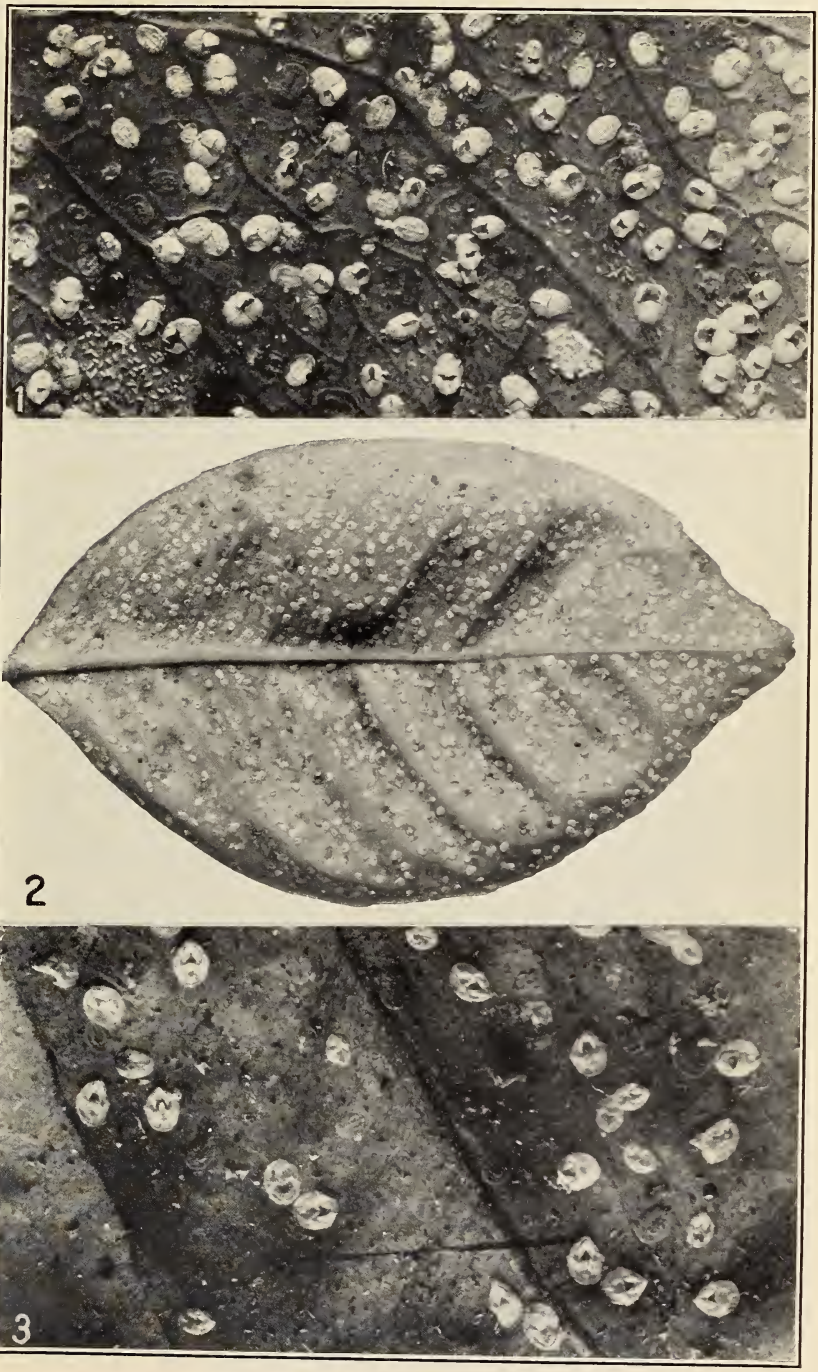
Description.

Although the citrus white fly is known to attack several species of plants, its special importance as a pest is owing to its injury of citrus trees, in which the infestation is confined to the leaves. The insect as commonly seen on trees is of the appearance of a small, thin, transparent or greenish-white scale entirely devoid of wings.

In the earlier stages of development, as hatched from the egg, it possesses three pairs of short, stubby legs and somewhat resembles in general appearance a small louse or mite. So small is the insect at this time and so transparent is it that only the closest observation will reveal its presence to the naked eye. In fact, persons unaccustomed to close observation might easily examine an infested leaf without discovering the presence of these young insects. This is the only time in the life of the immature insect in which it is able to move about the plant. After hatching from the egg the minute larva crawls about the leaves until it finds a situation suitable to its taste. This found, it inserts its elongate threadlike mouthparts into the leaf and then settles down to remain in this position until full grown. The juice of the leaf is extracted through this threadlike mouth. To allow growth, the hard outer skin of the young insect is cast off from time to time. The legs are lost with the first molt, so that in the later stages of development the insect is entirely without the power of locomotion.

With the third molt the insect passes from the so-called larval condition into the pupal stage (Pl. I). This is the last stage of development and the one in which the insect is most commonly noticed. At first thin and so pale green as to be almost transparent, it becomes thickened and opaque on approaching maturity. When almost mature a bright orange spot appears on the back and later two purple spots toward the anterior end. The insect at this time is about one-sixteenth of an inch long or practically the size of the head of a pin. These purple spots are the eyes of the adult and appear from three to eight days before the same is fully mature. When fully developed the pupa case splits down the back, allowing the adult to come out.

The adults are light orange-yellow in color and possess four wings, which enable them to fly about the tree or from one tree to another (Pl. II). This is the only stage in which the white fly possesses much activity, and were it not for the winged adults the mechanical control of this species would be quite easily accomplished. The eggs are deposited on the lower surface of the leaves. An individual female will average about 125 eggs during life. Usually many thousands of eggs are deposited on a single leaf, the leaf presenting an appearance as if sprinkled with grains of dust.



PUPA CASES OF THE CITRUS WHITE FLY.

Fig. 1.—Leaf showing pupa cases of the citrus white fly (*Aleyrodes citri*); also a few pupæ and eggs. Fig. 2.—Underside of orange leaf, showing heavy infestation by citrus white fly. Fig. 3.—Leaf showing pupa cases of the cloudy-winged white fly (*Aleyrodes nubifera*), an insect prevalent on citrus plants in Florida, and very closely related to *Aleyrodes citri*. (From Morrill and Back.)

ADULTS OF THE CITRUS WHITE FLY ON FOLIAGE OF ORANGE.

Fig. 1.—Tender growth of citrus swarming with adults of the citrus white fly. Fig. 2.—Leaf of same, enlarged. (From Morrill and Back.)

Distribution in the United States.

The citrus white fly in the United States has been recorded as existing under natural conditions in Florida, southern Georgia, South Carolina, Alabama, Mississippi, Louisiana, and Texas. In 1907 it was discovered in two localities in California, following which strenuous efforts were made toward its eradication. Recent reports[1] state that the insect has reappeared in one of these districts. In addition to the above citations the pest has long been known from greenhouses in many northern States.

The importance of the white fly as a citrus fruit tree pest is shown almost exclusively in those Gulf Coast States where citrus fruits are produced commercially. Although oranges are being grown quite extensively in Louisiana and Texas, and to some extent in Alabama, it is in Florida that the orange-growing industry stands forth as a great and most important one. The distribution of the white fly in Florida has become so general that it has been reported by Morrill and Back[2] as occurring to a greater or less extent in all but two of the 17 important citrus fruit-growing counties. All important agitation and efforts toward control have originated in this one State. The close association of this insect pest with the orange and grapefruit industry of Florida has led to its frequently being called the "Florida white fly" when referred to in other parts of the United States.

Injury.

The white fly is the most serious enemy of citrus trees in the Gulf Coast States. Considering the extent of its injury, together with the difficulty experienced in its control, it stands as without doubt the most serious pest to citrus-fruit production in the entire United States. Injury from the white fly may be considered from two standpoints—direct injury to the tree by loss of vitality through removal of sap, or injury produced from the presence on the leaves, branches, and fruit of the sooty-mold fungus which flourishes on the honeydew secretions from the white fly. Although the injury due to loss of sap is undoubtedly considerable, it is of small importance compared with the injury directly or indirectly resulting from the fungous growth, and were it not for this secondary consideration the present fear to the citrus-fruit grower of white-fly infestation would be largely eliminated. The sooty mold remains in a more or less nascent period during the winter months and early spring, but later develops rapidly, so that with the approach of summer it has heavily coated those trees severely infested with the white fly.

The fungus naturally follows the distribution of the honeydew, which is prevalent especially on the upper surface of the leaves and

[1] Monthly Bul. Cal. State Comm. Hort., vol. 1, no. 6, pp. 242–243, 1912.
[2] Bul. 92, Bur. Ent., U. S. Dept. Agr., pp. 25–26, 1911.

the upper half of the fruit (Pl. III). It is in these places that the development of the sooty mold is greatest. The mold may also be found to a greater or less extent on the branches and underside of the leaves. The injurious effect resulting from fungous growth on the leaves is due to the check which it places on the assimilative process that takes place within the tissues, retarding the availability of a normal food supply for the tree. The injury to fruit has been carefully worked out by Drs. Morrill and Back,[1] and the following statement is based on their investigations: The greatest injury by the white fly lies in the reduction of the number, size, and quality of fruit produced. Conservative estimates, based on extended observations, have placed the average yield in different white-fly infested groves in Florida as between 20 and 50 per cent below that of normal uninfested groves. In addition to this the packing size of oranges is reduced one or two grades, while the increased number of culls due to retarded ripening and other causes materially lowers the market value of the crop. Moreover, fruit coated with sooty mold must be washed before marketing. It has been shown by Dr. G. Harold Powell,[2] formerly of the Bureau of Plant Industry of this department, that decay in shipment is greatly increased in washed fruit. Hence the cost of washing, augmented by the additional loss from decay in washed fruit over that which is unwashed, is an added loss from white-fly infestation.

Summing up the whole situation after their experience, Drs. Morrill and Back estimate that in the average infested grove the total loss from the white fly may be placed at about 45 to 50 per cent of the value of the orange crop. Considering that fully 45 per cent of the citrus groves in Florida are infested by the white fly it has been estimated that in money value this would amount to more than half a million dollars annually.

Methods of Control and Their Efficiency.

Greater effort has been devoted to the control of the white fly than of any other pest in the Florida citrus belt. Agents of this department commenced studying the white fly as early as the eighties, and since 1906 this bureau has retained a corps of investigators continuously in the field testing the various possible methods toward its successful control. Entomologists from the Florida State Experiment Station have also been working along similar lines for many years. The efforts of these different scientists have resulted in the proposal of three distinct methods for control of the white fly: (1) Fumigation with hydrocyanic-acid gas, (2) spraying with various insecticides, and (3) the utilization of several fungous diseases of

[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.
[2] Bul. 123, Bur. Plant Industry, U. S. Dept. Agr., 1908.

FIG. 1.—ORANGE COVERED WITH SOOTY MOLD (From Morrill and Back.)

FIG. 2.—LEAF OF ORANGE COATED WITH SOOTY MOLD (From Morrill and Back.)

this insect already prevalent in certain parts of Florida. As to the comparative efficiency of these three methods authorities are not universally agreed, but from an unbiased point of view it would seem that each has its advantages over the others within certain more or less restricted fields. A discussion of these restrictions is unnecessary in this place. Suffice it to say that by 1909–10 results of investigations had not established universally in the minds of Florida orange orchardists the absolute commercial efficacy of mechanical-control methods.[1]

CONDITIONS LEADING TO THE DEMAND FOR A SEARCH FOR NATURAL ENEMIES OF THE CITRUS WHITE FLY.

The climate of Florida is, in general, very damp, a condition especially suitable to the free development of fungous diseases. Six different fungi have been recorded as attacking the citrus white fly, and their resultant destruction in localities of much humidity appears at times to total a high percentage.

Following a movement toward efficient organization of the citrus industries of Florida, the extent of damage which results from white-fly infestation, as well as its direct bearing on the market quality of the fruit, was brought forward with renewed force. Considering the failure at that time of the mechanical methods to meet adequately the demands of the orchardists, coupled with the apparent partial efficiency of fungous diseases, the time seemed ripe that the popular idea of control by natural enemies should gain a devoted following.

This theory of control by natural enemies, in brief, is that all life in its native home is kept in check by other forms of life which prey upon it; in other words, that all nature is in a state of equilibrium. Chief among these natural factors of control in the case of insect pests are other forms of insect life which are parasitic and predatory on the noxious form. In recent years much attention has been devoted to the discovery and subsequent introduction from one country into another of beneficial insects for utilization in attempted control of certain of our more important insect pests. One of the earliest importations into America was that of a small lady-beetle, *Novius cardinalis* Muls. For several years a large scale insect called the cottony cushion scale (*Icerya purchasi* Mask.) had been producing such extreme injury to the orange and lemon groves of California that the industry was threatened with ruin. Mechanical means of control proved ineffective. In the belief that the insect had been introduced into the United States from Australia, Mr.

[1] Fumigation, though highly efficient in itself as a factor in the control of the citrus white fly, has not met with general adoption, largely because of certain practical considerations which render it unavailable economically under present conditions in Florida. However, recent results with special oil sprays have placed the control of the white fly on a very satisfactory commercial basis.

Albert Koebele was sent by Prof. C. V. Riley, then chief of this office, to that country in search of natural enemies. His discovery of *Novius cardinalis*, its introduction into California in 1889, and its subsequent rapid development and spread soon resulted in such a complete destruction of the cottony cushion scale that the insect has no longer been a factor in citrus production in that State.

This remarkable work of Novius resulted in a great stimulus to the efforts to bring about insect control by means of natural enemies and has become an historical event in applied entomology. It might be added that the universal success against the cottony cushion scale by a single natural enemy has never since been duplicated in the case of any other insect pest. From this most successful introduction to the present day many more or less successful attempts in the utilization of natural enemies have been made. The most extensive work of its kind ever undertaken is that now being carried on under the direction of this bureau in New England against the gipsy and brown-tail moths, which are highly destructive to forest, orchard, and shade trees in that region. These insects were accidental introductions from Europe, and on that continent are preyed upon by numerous natural enemies. Extended efforts in importing all available parasites and predatory insect enemies of these two pests and in establishing them in New England have met with marked success.

Because of these facts and others of a like nature a demand developed in Florida for an exploration of foreign countries to discover if possible the natural enemies of the white fly. Such exploration had been heartily recommended by the various investigators of this bureau who had been working on the white fly problem in Florida, and was also supported by the Florida Experiment Station and by orange growers. The partially effective control by the various fungous enemies of the white fly was an additional argument for the introduction of the natural insect enemies to supplement the work of these beneficial fungi.

As the result of these demands Congress set aside a special appropriation, in 1910, for the purpose of searching the world to discover the native home of the citrus white fly and learning if it was there held in check by natural enemies. If natural enemies could be found these were to be collected, brought to this country, and, if possible, established in Florida.

PREPARATIONS FOR THE SEARCH.

The writer was asked by Dr. Howard, Chief of the Bureau of Entomology, to undertake the mission of searching for the native home of the white fly and of ascertaining if it was anywhere attacked by natural enemies other than those already known in Florida. After bringing to a satisfactory close an investigation of the use of hydrocyanic-acid

gas for fumigation purposes in the destruction of scale-insect pests of citrus-fruit trees in southern California—work which had been in progress for three years—the writer proceeded to Washington to make final arrangements for his departure on the mission.

Since the white fly is reported from the United States as being primarily an enemy of citrus it was considered that its distribution would be limited to those regions in which citrus trees occur, and naturally it followed that these were the places to which travels should be directed. It is well known that citrus trees are grown to a greater or less extent in the semitropical and tropical zones throughout the world. The most tenable supposition is that they originated in southeastern Asia, whence their distribution, either directly or indirectly, to those countries in which they are at present to be found.

In the collections of this bureau are specimens of the citrus white fly which have been taken on orange trees in southern China and in Japan. On his way eastward the writer passed through San Francisco on the day that Mr. George Compere, the well-known collector of natural enemies of insects for the State of California, was returning from the Orient with supposedly valuable introductions. An examination of an orange tree which Mr. Compere had secured in Japan revealed the presence of the citrus white fly, thus corroborating previous records from the Orient.

The collection of Aleyrodidæ of the late William Maskell of New Zealand is now in the custody of this bureau. In examining type material from this collection of a species named *Aleyrodes aurantii* Mask., collected on orange in the northwestern Himalayas of India, Prof. A. L. Quaintance, of this bureau, an authority on Aleyrodidæ, decided that this Indian species was none other than the citrus white fly of Florida, *Aleyrodes citri*. Having the above information at hand it was at once evident that special attention should be devoted to a search of that part of the Orient having a tropical or semitropical climate.

The present known distribution of the citrus white fly throughout the world is shown in figure 1.

INVESTIGATIONS IN EUROPE.

On July 31, 1910, passage was taken on a steamer from New York en route to Spain via Gibraltar. This first stop was made in response to a request from the Minister of Agriculture of Spain that the writer demonstrate before the orange growers of that country the procedure of hydrocyanic-acid gas fumigation in the destruction of scale-insect pests of citrus trees. The orange and lemon trees of Spain are seriously affected by several species of scale insects. Satisfactory control of these insects had never yet been accomplished, while many of the orchardists were in despair lest their trees should be ruined.

The month of August was spent in southern Spain, chiefly at Malaga and Valencia in company with Comte de Montornes, Royal Commissioner of Agriculture to the Province of Valencia, and Leopoldo Salas, Agricultural Engineer to the Province of Malaga. During this time the equipment essential in fumigation was acquired until a crew was properly fitted for field work. Demonstration work was then carried on in training the crew until it had become familiar with the general procedure of fumigation. Meanwhile experimental work was being carried on, the results of which furnished a basis for dosage against the insects treated.

Abundant opportunity was found during this demonstration to study the insect pests of citrus trees in different parts of the country.

FIG. 1.—Map showing present known world distribution of the citrus white fly (*Aleyrodes citri*). (Original.)

The citrus white fly, however, could not be found in Spain. From Spain the writer continued to Italy and Sicily and these countries were searched but failed to reveal the presence of *Aleyrodes citri*; nor has this insect ever been found in European orchards. Thus the great citrus belt of Europe, although beset with many injurious insect pests, most of which are mentioned in the appendices of this bulletin, has not yet become infested with this particular menace, the citrus white fly, which has proven so discouraging to the orchardists of Florida.

INVESTIGATIONS IN CEYLON.

Leaving Naples, direct passage was taken to Ceylon, which was reached September 30. Citrus fruits are not grown commercially in Ceylon, their production being confined to scattering trees, in yards and gardens, and are grown for decorative purposes as well as for fruit. Orange trees do not appear to grow with much vigor

on this island, and the fruit produced is inferior in size and quality. When picked, the rind is perfectly green, although the flesh may be fully matured. This failure of the fruit to color—a condition noticed in other countries lying near the equator—is doubtless attributable to the excessive dampness of a tropical climate.

The orange trees examined on this island were found entirely free of the citrus white fly. Through the kindness of Dr. E. E. Green, Government Entomologist, his extensive collection of Aleyrodidæ from all parts of Ceylon was examined, but without evidence of the citrus white fly. When we consider the above data it does not seem at all likely that the citrus white fly occurs in Ceylon.

INVESTIGATIONS IN INDIA.

General.

The journey was continued from Ceylon to India, which was entered at Tuticorin, the southernmost seaport of importance. Thence the writer proceeded by rail to Calcutta, his object in visiting this city being to obtain all possible information as to the distribution of citrus trees throughout the Indian Empire. Calcutta is the one city which the naturalist seeking information about this country will first desire to reach. In addition to the natural advantages resulting from the fact that it has been the headquarters of the Government and that it is the largest city with very much the largest white population of any Indian city, it contains the Indian Museum, the largest if not the oldest institution of its kind in the Orient. This building is especially rich in natural history material. Many investigators are employed at this Government institution for research work and to classify and bring to the notice of the public information on the natural history and resources of this great yet little known country.

Through the kindness of Dr. F. Anondale, Director of the Indian Museum, access was had to the entomological collections contained therein. An examination of material of the family Aleyrodidæ brought to light some severely infested orange leaves which were labeled as collected in the northwestern Himalayas about 1893, it being stated on the label that duplicate material had been sent to William Maskell, the late eminent entomologist of the New Zealand Institute. It happened that about 1894–95 Maskell described a new species of Aleyrodes as occurring on orange in the northwestern Himalayas, calling it *Aleyrodes aurantii*. Hence it was at once evident that the material found in the Indian Museum was identical with the *Aleyrodes aurantii* of Maskell. Prof. Quaintance, of the Bureau of Entomology, in examining the Maskell collection, came to the conclusion that the *Aleyrodes aurantii* of Maskell was the same species as *Aleyrodes citri* R. & H., the citrus white fly of Florida. The writer's

examination of material in Calcutta corroborated Prof. Quaintance's determination that the citrus white fly occurs in India. Moreover, infested orange leaves from a place in the northwest called Kulu were also found in the museum, and this gave the writer a definite locality for the white fly in India. Kulu is such a difficult place to reach that it was decided to visit first other more available localities in the northern part of the Empire.

During his stay in Calcutta the writer interviewed all available authorities who had acquaintance with agricultural conditions in different parts of that country, but little definite information relative to the distribution of citrus fruit trees was secured. It must be considered that agriculture in India is for the most part in a very primitive condition. Commercial orange growing, as we know it in America, does not exist, but the production of fruit is confined almost exclusively to individual or small patches of trees in yards and native gardens, both on the plains and in the hills or lower elevations of the mountains. (See Pl. IV.) In the latter places they are sometimes grown among the trees of the forest. However, occasionally one sees larger plantings which in extreme instances might reach 5 or even 10 acres in size.

The Botanical Gardens.

The greatest aid to the writer in his searches for citrus fruit trees were the Government botanical gardens which are situated in different parts of the Empire. (See Pl. V.) The more important of these gardens have European directors—men usually familiar with agricultural conditions in their respective provinces. Then, too, most of these gardens contain a large variety of fruit trees. The largest and oldest one is situated near Calcutta. From interviews with the authorities at this garden the writer learned that the oldest garden in Upper India was situated at Saharanpur and also that citrus trees are grown to some extent in this locality.

For this reason, as well as because this would be the most feasible place in which to secure information relative to the distribution of citrus trees in northern India, the writer proceeded to Saharanpur in the latter part of October, 1910. This was a most fortunate move, for in Mr. A. C. Hartless, the superintendent of the Saharanpur Botanical Garden, was found a most capable botanist, whose familiarity with the conditions in India and wide acquaintance with botanists and horticulturists, acquired during 25 years of continuous service in different parts, opened to the writer a source of information pertaining to this problem the equal of which was available in no other one place.

A large number of citrus trees of many varieties are grown in this garden. Orange, lime, and grapefruit are also scattered throughout the immediately surrounding region.

Discovery of the Citrus White Fly at Saharanpur.

An examination of orange trees at Saharanpur soon led to the discovery of the citrus white fly, and subsequent search revealed the fact that it was of general distribution hereabouts. The insect at this time had reached the pupal stage. Specimens of the fly could be found on practically all trees examined, but the infestation was so light that the insect was in no way a serious pest. Of the insects infesting the leaves only a small percentage was living. The trees containing the largest number of living insects were noted to be the ones with the densest foliage and those protected by large overshadowing ornamental trees. In no instance was a tree affected by "sooty mold" (*Meliola* sp.).

Discovery of Cryptognatha flavescens, the Lady-Beetle Enemy of the Citrus White Fly.

Closely following the discovery of the white fly, several minute larvæ of a coccinellid were seen on fly-infested trees, and later it was found that these were feeding on the young pupæ of the white fly. This happy discovery proved conclusively that *Aleyrodes citri* is attacked by a natural enemy in its native home, and thus one part of the mission on which the writer had been sent was successfully fulfilled. Later developments showed that the adults of this species were small reddish-brown beetles, about one-tenth of an inch in length.

Several days were spent in a careful and exhaustive search throughout this region, with the result of finding about 200 specimens of the lady-beetle. These were collected by placing large sheets of cloth underneath the trees early in the morning before the insects had become active and then beating the branches with sticks. In this manner much ground could be covered in a short time.

About 100 specimens of the insect were placed in a small, specially made wooden box containing two chambers connected by an opening about the size of a 50-cent piece. One of these chambers was loosely filled with damp sphagnum moss, the other with dry fiber from a palm tree. Such packing allowed the insects free movement and at the same time reduced possible injury from rough usage to a minimum. The box was so constructed as to allow necessary aeration.

This box was forwarded to the American consul-general at Calcutta, who placed the same in the personal charge of the captain of a cargo steamer sailing direct from Calcutta to the United States. All insects had died before their arrival in Florida.

A second sending made by letter mail also failed to come through in good condition.

This beetle was identified by Mr. E. A. Schwarz, of the Bureau of Entomology, as *Cryptognatha flavescens* Motsch.

Discovery of the Brown Fungus, Ægerita webberi.

During this examination of the Saharanpur region the writer's attention was frequently called to the presence of a brownish fungus attacking the white fly on trees in well-shaded positions. It seemed identical to all appearances with the Florida brown fungus (*Ægerita webberi*), yet in order to be certain in this determination a quantity was sent to Prof. H. S. Fawcett, formerly of the Florida Agricultural Experiment Station, an authority on fungous diseases of the white fly. His identification of it as *Ægerita webberi* was conclusive in showing that this fungus occurs in India as well as in Florida.

The writer failed to find this fungus except in the region about Saharanpur. A great deal of exchanging of plants, especially of citrus trees, between the botanical garden at this place and certain nurserymen in Florida has been going on for many years, and it seems quite likely that the brown fungus was introduced from Florida into India through these exchanges.

Searching at Lahore.

Leaving Saharanpur on November 10 the search was continued northward into the Punjab, and Lahore, the principal city in this Province, was made temporary headquarters. It is located toward the center of a broad plain and is less than 500 feet above sea level, although more than a thousand miles inland from the ocean. The plain is bordered on the north and east by the gigantic Himalayas, while it opens southward in an unbroken stretch to the sea. The climate is generally dry, the temperature of the summer being excessively hot, frequently reaching to between 115° and 120° F., while the winters are comparatively cold, the minimum temperature averaging between 35° and 50° F. It is very seldom that the temperature falls below 35° F.

Orange trees are abundant at Lahore, being found in almost every yard, as well as being the most common plant used for hedges. In the vicinity of this city they are grown to a considerable extent for commercial purposes. This consideration, coupled with the inducement offered by the presence of a large botanical garden, led to the decision that Lahore was the most suitable situation in the north for continuing our efforts, and later developments resulted in demonstrating it to be the most suitable locality in all India. Considering the abundance of orange and lime trees as well as their diverse conditions of cultivation, existing, as they did, from dense growths of seedling trees, entirely uncared for, to well-cultivated orchards of healthy budded stock, it seemed that if the white fly and natural enemies were to be found anywhere in northern India this must be the place.

FIG. 1.—A NATIVE HOUSE IN EASTERN INDIA WITH ORANGE TREES IN THE YARD. (ORIGINAL.)

FIG. 2.—HOW ORANGES ARE GROWN IN JAVA. (ORIGINAL.)

[To a large extent the production of oranges depends upon orange trees planted in gardens and about native dwellings. The fruit is largely of the tangerine variety.]

ORANGE PRODUCTION IN INDIA AND JAVA.

FIG. 1.

FIG. 2.

Some of these gardens contain many citrus trees. In the one at Lahore, of which figure 1 is a view, the citrus white fly was found attacked by two natural enemies. The living material transported to the United States was largely collected in this garden. (Original.)

SCENES IN THE BOTANICAL GARDENS OF INDIA.

A careful search, covering several days, resulted in determining that the white fly was of widespread distribution. The infestation was quite similar to that already described as occurring at Saharanpur. Although of general distribution, the fly was in no place so abundant as to be a serious pest. The smut so prevalent in white-fly infestations of Florida was almost entirely absent. While it was not a difficult matter to find large leaves in well-protected, densely foliated trees that contained large numbers of white flies, few were in a living condition. Those alive were in an early stage of pupation.

Discovery of Prospaltella lahorensis, the True Internal Parasite of the Citrus White Fly.

During the investigation at Saharanpur a few pupa cases of the citrus white fly were noticed to differ somewhat in appearance from those of normal shape. Some of these contained very small holes which were of such a character as could easily have been made by a lady-beetle or some other biting insect. However, when large numbers of these abnormally thickened pupa cases were found at Lahore, and always with a small rounded hole in the exposed surface, it was very apparent that this condition was the result of internal parasitism. Considering the type of the host as well as the character of the opening, one was at once led to infer that the parasite was of a hymenopterous species. The cold weather at this time of year had driven almost all insect life into hibernation, so it was impossible to find any living parasites. A large quantity of leaves containing insects which had been parasitized was collected and sent to the Bureau of Entomology in Washington. A careful examination of this material resulted in finding five dead specimens of a very minute insect, which Dr. Howard, Chief of the Bureau of Entomology, determined as belonging to the genus Prospaltella, of the hymenopterous subfamily Aphelininæ.

In stating the results of this examination Dr. Howard wrote:

> The specimens on leaves sent in by Mr. Woglum have been examined with great care. None of the full-grown larvæ or nymphs contained pupal parasites, but five specimens of a very minute aphelinine of the genus Prospaltella were found dead and attached to the orange leaves in the vicinity of perforated Aleyrodes. The size of these specimens is such as to justify the conclusion that they had issued from aleyrodids, and their juxtaposition and the known habits of the genus confirm this conclusion.

As the insect was new to science, it was described as follows by Dr. Howard:[1]

> *Female.*—Length, 0.54 mm.; expanse, 1.42 mm.; greatest width of forewing, 0.25 mm. Antennæ long, not clavate; scape long, slender; pedicel nearly as broad as long; first funicle joint somewhat longer than second; second and third subequal; club equal in length to second and third funicle joints together; terminal segment of

[1] Journal of Economic Entomology, vol. 4, no. 1, p. 132, 1911.

club slightly longer than middle segment, basal segment again slightly shorter. Forewings broad, with moderately long bordering cilia; disc uniformly covered with minute cilia; stigmal vein rounded below, its anterior margin for a time parallel with costa; marginal vein faintly indicated, its base joining stigmal in an acute angle. (In this respect this species differs from all other known species of its genus.) General color light yellow; all legs pallid; eyes dark; ocelli coral-red; antennal club dusky; wings hyaline, wing veins dusky.

Male.—Of practically the same size and structure as the female, but differing in color. The coloration closely resembles that of *Aspidiotiphagus citrinus*, to which it bears a superficial resemblance; pronotum brownish; mesonotum orange yellow; metanotum and epimerum brownish; abdomen dark brown except at base and tip where it is lighter; hind femora dusky at tips; wing veins distinctly fuscous, considerably darker than in female.

Conclusions Drawn from Situation at Saharanpur and Lahore.

Our searches at Saharanpur and Lahore had resulted not only in the discovery of the citrus white fly, but, what was especially important, the discovery that it was being attacked by both a predatory enemy and a true internal parasite. It was at once evident that our next duty lay in attempting to collect and transport to Florida living material of these beneficial insects. Unfortunately the season at this time was so well advanced that practically all insect life was in a dormant condition, so that the collecting of living material during the next few months was impossible. Rather than remain inactive in upper India until the following spring, it seemed best to continue the search throughout India and into China with the hope of acquiring a broad grasp of the white-fly situation throughout the Orient. Having the situation thus in hand, we would know whether or not there were other regions equally prolific in natural enemies of the white fly. Such information would be of great value to all future work in this particular field.

Aleyrodes citri in India.

With the exception of the lower part of the peninsula practically all of India suitable to the growing of citrus fruit trees has been searched. The writer has examined orange trees at Peshawur, the frontier city in the northwest near the entrance to the Khyber Pass; along the lower elevations of the Himalayas (Pl. VI, fig. 2) at Dehradun; in the United Provinces; in Sikkim below Thibet; and eastward into the Khasia Hills of Assam (Pl. VI, fig. 1). In the west the writer has been among orange trees at Poona, in the Bombay Presidency, and eastward at Nagpur, in the Central Province. Much of the intervening territory between these outposts of travel has been covered.

As a result of these travels it can be stated that in all places visited in India, in which oranges were grown, infestations of the white fly were to be found. This is equivalent to stating that this aleyrodid

FIG. 1.—COUNTRY BOAT, UTILIZED FOR TRAVELING IN ASSAM.

It is so constructed as to afford protection from heat of sun during the day, and one may also sleep within at night with some comfort. (Original.)

FIG. 2.—TRAVELING IN THE OUTER HIMALAYAS.

The traveling in this region was performed for the most part on horseback, with native bearers for carrying provisions. (Original.)

TRAVELING IN INDIA.

is distributed throughout India south of the Himalaya Mountains. (See fig. 2.)

Evidence of parasitism was seen in practically all localities infested with the white fly.

FIG. 2.—Map showing localities in which the citrus white fly (*Aleyrodes citri*) was found in India. (Original.)

INVESTIGATIONS IN BURMA, JAVA, SOUTHERN CHINA, AND THE PHILIPPINE ISLANDS.

Leaving Calcutta December 24, 1910, the writer continued the trip to Burma with the idea of searching a large citrus section reported to be in the vicinity of Moulmein, Lower Burma. A week's search in this region revealed about a half dozen dying orange trees which were free of the white fly. Although reliable information was received from an engineer in the Burmese public works department that orange trees occurred wild some 50 miles to the east in the mountains on the border between Lower Burma and Siam, as well

as far to the north in the Upper Shan States on the Chinese border, the limited time at the writer's disposal rendered it inadvisable to explore these distant and very inaccessible regions. Instead return was made to Rangoon, where a steamer was boarded en route to Java via Penang and Singapore.

Batavia was reached on January 16 and a few days were spent hereabouts in making short journeys into the surrounding country. To the biologist visiting Java, the one place to which his attention is particularly directed is Buitenzorg, the seat of the far-famed Botanical Garden, which is situated about 60 miles from Batavia, the capital and principal seaport of the island. After having acquired a knowledge of Batavia and its surroundings, naturally the next move was to proceed to Buitenzorg. Itself most beautiful and surrounded by equally attractive country, this locality is a veritable tropical paradise. The garden is immediately adjacent to the city. Its great variety of plants, beauty of arrangement, and size would place it in the foremost rank of the botanical gardens of the Tropics, while the extensive and well-equipped laboratories for research, as well as a splendid museum, probably afford the investigating biologist a combination of desiderata unsurpassed in the Tropical Zone.

Orange and grapefruit trees occur in the garden and are found scattered throughout the surrounding country. A week was spent in this locality, during which many trees were examined, yet without evidence of the citrus white fly.

Through Mr. Max Wigman, botanist of the Buitenzorg Gardens, detailed information was secured relative to the localities in Java in which citrus trees were most prevalent. Utilizing this information during the following two weeks the journey was continued through the western half of the island. Orange and grapefruit occur throughout this region, the plantings for the most part consisting of scattered trees along the roads and paths or in gardens about the native houses.

At no time during the writer's travels in western Java were there seen as many as a hundred orange or grapefruit trees in a single orchard.

The citrus fruit trees were attacked by a number of insect pests, but no evidence of *Aleyrodes citri* could be found. So many trees were examined in different parts of the island that it would seem a safe conclusion that the citrus white fly does not occur in Java.

Leaving Java early in February (1911) a boat was taken to Singapore, where transfer was made to a steamer sailing direct to Hongkong. On arrival at the latter port a cablegram was received from Dr. Howard advising that a return trip be made to India and that effort be made to secure living material of the two natural enemies

of the white fly for transfer to Florida. It was decided to spend a fortnight in southern China before taking return passage, as this would enable the writer to gain some information on conditions in that little-known country.

It was learned from Mr. Tutcher, superintendent of the Hongkong Botanical Garden, that oranges were grown extensively over a broad range of territory inland from Canton, and that a second large citrus-fruit region was westward of the seaport of Swatow. As Mr. Tutcher kindly consented to loan the services of one of his native collectors who was familiar with the Canton region, arrangements were begun for investigating that territory as soon as passports were available.

Application for a passport into the interior was filed at Canton with the American consul general, who stated that it would be about 10 days before the same could be prepared. After returning to Hongkong the writer decided to utilize the delay occasioned by the passport by a trip of inspection to the Philippines, which are about two days by water from this British seaport. While awaiting the sailing of a steamer for Manila a day was spent at Macau, a Portuguese settlement near Hongkong. Some orange trees infested with *Aleyrodes citri* were seen here, thus giving a new and definite record of this insect in southern China.

Manila was reached on February 28. Through the assistance of officials in the bureau of science a number of orange trees were found in this city and carefully examined. No white flies were seen. From information available it would seem that very few oranges are produced in the Philippine Islands. The only localities in which citrus fruits are grown commercially are Santo Tomas and Tanauan, in the Province of Batangas. These localities were examined, but no white flies could be found.

While in the Philippines the writer was taken ill and confined to the hospital throughout the month of March. This illness came at a very critical period and delayed an early return to India. Hastening, as he did, from the hospital before having fully recovered, it was nevertheless impossible to reach India until the last of April, when the spring season was well advanced.

FURTHER INVESTIGATIONS IN INDIA.

Landing in Bombay on April 22, necessary paraphernalia and provisions were at once collected and a native interpreter engaged preparatory to starting inland.

Concentration of Efforts at Lahore.

The writer's objective point was Lahore, in the Punjab, about 1,200 miles inland from Bombay. Previous experience had shown this locality to present the best field of any place in all India for

possible successful operations. Not only were there a great number of citrus trees in this region, but the infestation of the white fly as well as the percentage of parasitism exceeded that of any other place visited. This was also one of the few places in India in which young nursery trees were available in large numbers. Being also the seat of a large botanical garden which contained many citrus trees, it afforded excellent facilities for the purpose in hand, and thus was the logical place in which to concentrate efforts.

A stop was made en route at Saharanpur, where success had been achieved the previous year in the collection of *Cryptognatha flavescens*, the predatory enemy of the white fly. Diligent search this time revealed very few living Aleyrodes; so after employing from Mr. Hartless, the superintendent of the garden, a "molle" or gardener who had assisted the writer the previous year, the journey was continued to Lahore.

A careful canvass of the orange and lime trees of the Lahore region was at once started in order to ascertain the prevalent condition of the white-fly infestation. Several days of laborious endeavor covering much of this locality resulted in the finding of a very light or scattering infestation of living Aleyrodes. The number was so small as to be worthless for use in breeding or parasitic work.

Confronted with this discouraging outlook, a trip was made to Gujranwala, about 50 miles north of Lahore and the greatest commercial orange-producing center in northern India. The condition of the white fly on citrus trees here was quite comparable with that at Lahore. Few living insects could be found, although the number of dead specimens on some trees was large. The previous autumn a small garden of an ornamental bush (*Jasminum sambac*), whose flowers are valuable for making perfumed oils, was found surrounded by orange trees. These Jasminum bushes were severely infested with *Aleyrodes citri;* in fact, it was the most severe infestation seen in all India, so much so that the leaves were blackened with a crust of sooty-mold fungus. As he felt confident that this garden would furnish a splendid breeding ground for the white fly, the discouragement of the writer can be well imagined when on examining this garden it was found that the extreme temperature of the previous winter had frozen back most of the bushes and almost eradicated the fly. Returning to Lahore, a most careful search was continued, with the ultimate result of discovering in one part of the botanical garden a well-protected hedge which was well infested with the white fly. This fortunate discovery constituted the basis of future operations.

Discovery of Living Parasites.

Immediate attention was next devoted toward the discovery of the parasite *Prospaltella lahorensis*, which the work of the previous

autumn had shown to occur throughout this region. Efforts soon were rewarded with the finding of living parasites in very small numbers on the more protected parts of the infested hedge.

Considerations in Collecting and Transporting Prospaltella lahorensis.

As explained under the discussion of the citrus white fly, this insect very shortly after hatching from the egg settles down on the underside of the leaf to remain in a stationary position throughout its life. If the leaf is removed from the tree, the insect dies when nourishment is no longer available. *Prospaltella lahorensis*, being a true internal parasite of the white fly, is dependent on the living condition of its host in order to attain maturity. From a consideration of this situation it was at once evident that the only practicable way of transporting the parasite to America in a living condition was by means of healthy nursery trees infested with parasitized *Aleyrodes citri*. Moreover, the journey from India to Florida occupies between five and six weeks, while the entire life cycle of the parasite at high temperatures is of about three weeks' duration. This would mean that even if the parasite left India in the egg stage a complete cycle of development would take place and the adults emerge before America was reached. This latter feature necessitated the presence of living Aleyrodes throughout the journey so that the parasites at time of their emergence would have material upon which to work.

As small nursery trees are alone practicable for transportation over great distances, it was at once evident that the success of the mission depended on obtaining young trees well infested with the white fly. Young orange trees were available in sufficient quantities at the Lahore garden, but all were free from living white flies. Young fly-infested trees had not been seen anywhere in that country. The problem thus resolved itself into the artificial infestation of the trees.

Destruction of Young Growth of Citrus Trees by Insect Pests.

A large number of young orange trees from 1 to 4 feet tall were dug and placed in earthenware pots. As these trees contained no young growth, they were placed in a shady place and kept very moist. It is well known that the adult white fly prefers tender growth for oviposition. Young shoots soon developed, but no sooner did the leaves begin to expand than they were immediately attacked so severely by a lepidopterous leaf-miner, *Phyllocnistis citrella* Stainton (Pl. VII, fig. 1) as well as by a bud-worm (*Agonopteryx* sp.), that the young leaves of all the plants curled and shriveled before reaching maturity, thus rendering the plants worthless for the purpose desired.

In order to avoid the destruction of young growth by these two insect pests cloth houses were constructed and into these were placed

a second set of potted nursery trees (Pl. VII, fig. 2). The trees were carefully examined before being introduced into the house in order to destroy any of the pests that could be seen. This was not difficult of accomplishment, as the pests pupated in the trees. Inspection was continued every few days so that the plants were soon free of the pests and in due time the development of young growth followed.

Notes on the Life History of Aleyrodes citri in Northern India.

The following notes on the life history of *Aleyrodes citri* on citrus were made at Lahore during 1911 and might be said to be typical of this insect in the great plains of northern India. Observations made at different times of the year in other parts of India would tend toward the probability that the development recorded in the northern part would also be more or less applicable to central India.

On May 1–4, 1911, the earliest dates of observation, the white fly was in the egg and larval stages. Calculating on the basis of the conclusions of Morrill and Back in their white-fly investigations in Florida that during the spring the duration of the egg stage averages somewhat less than two weeks, it would appear from the stages of development existing at Lahore on May 1 that the first brood of adult flies had emerged during the earlier part of April. This conclusion was somewhat corroborated by information from a native entomologist who stated that he had seen adult Aleyrodes in great numbers during the first part of April about the citrus hedge which the writer had found well infested and which he had selected as a basis for operations in collecting. Circumstances prevented a close observation of white-fly development between the middle of May and June 11, but an examination on the latter date showed the insects to be in the pupal stage. By June 24 the pupæ were almost fully matured and in a few individuals the purple eyes of the adults had commenced to be prominent. On June 25 a small number of adults emerged and this emergence continued during the following two or three days. Emergence had stopped and practically all adults disappeared by June 29. From this time throughout July and up to August 20, a period of about eight weeks, the insects appeared to remain perfectly dormant. The last 10 days of August were a period of great activity. Excretions of honeydew appearing on the pupæ between August 20 and 25 marked the first evidence of activity following their dormancy during the hot, dry summer. From August 26 to 30 the pupæ rapidly thickened and the purple eyes and whitish wings of the adults became evident through the thin pupal covering. The first adults commenced to emerge on August 31, and within a week or ten days the flight was as its height. By September 13 practically the entire brood had emerged. On September 20 very

FIG. 1.—YOUNG CITRUS SHOWING LEAVES OF TOP SHOOTS DEFORMED BY ATTACKS OF A LEAF-MINER (PHYLLOCNISTIS CITRELLA).

At certain times of the year in northern India practically all new growth on young trees is affected by this insect. (Original.)

FIG. 2.—CLOTH CAGES PLACED OVER YOUNG CITRUS TO PROTECT THEM FROM THE RAVAGES OF THIS LEAF-MINER.

The destruction of young foliage on trees as soon as it appeared necessitated artificial manipulation in order to avoid the leaf-miner (*Phyllocnistis citrella*). Two cloth cages were constructed, and in these were placed potted plants. After several hand pickings the plants were freed of the leaf-miners, and the cloth protection permitted the young foliage to develop. (Original.)

few adults remained in flight, while the first eggs deposited were hatching. All eggs were hatched by October 5 and by October 20 many insects had reached the pupal stage.

Investigations at Rajpur and Saharanpur revealed conditions comparable with those at Lahore. Observations throughout northern India in November of the previous year (1910) showed the insect at that time to be in the pupal state. From a consideration of these conditions found in two different years it is evident that the white fly passes the winter in northern India as a pupa.

Number of Broods of the Citrus White Fly.

It has been stated by Morrill and Back that while there may be in Florida from three to six generations, adult flies are found in greatest abundance only during three more or less distinct periods, or generally speaking, there are three broods of white flies each year. Strictly speaking, there is great irregularity of breeding and overlapping of generations so that adult white flies may be found in varying numbers at all times except during the colder periods of winter. In all this irregularity, however, there stand out in prominence three general broods—a spring, a summer, and an autumn one.

Turning to northern India we find a different condition. Here there were two very distinct broods on citrus trees in 1911, adults of the first emerging in early April and those of the second during the first part of September. So far as the writer's observations extended these broods were sharply defined and without overlapping generations. In fact, so sharply defined were these two broods that no adult flies were seen outside of the two normal periods of emergence with the exception of a very few during three to four days in June. The latter emergence was due to a preceding period of high humidity accompanied by slight rains.

The Effects of Temperature on White-fly Development.

The climatic conditions of the plains of northern India are very different from those of Florida, and the resultant effect on the development of the white fly is equally apparent.

Whereas the winters in the Punjab of India average colder than in Florida the summers are very much hotter. During the months of July and August the average daily mean temperature in central Florida is 82° F., while during the same period in 1911 at Lahore it averaged 96° F., or 14° higher. The average daily mean temperature at Lahore for the months of May, June, July, and August was 94° F. and the average maximum temperature for the same period was 107° F. Such high temperatures have naturally a deterrent effect on insect development. Most of these days are bright and sunshiny, and so penetrating is the direct action of the sun that

Europeans require heavy protection in order to withstand it. Then frequently hot blasting winds blow with great violence, stirring up the dust in dense clouds and rendering life doubly uncomfortable.

In the direct rays of the sun the temperature during this time often exceeds 150° F. Failing rains cause vegetation to dry up and insects develop with difficulty. The following instance shows the effect of drought on the white fly:

In the Government Horticultural Garden at Lahore there is a very large nursery containing small orange and lemon trees. These trees were free of living Aleyrodes with the following exceptions: At one side of the nursery there was a large, densely foliated deciduous tree which overshadowed a number of orange trees. Some of these trees which were more densely shaded contained a small number of living white flies. Near the center of the nursery was a densely foliated tree about 10 feet tall, against the base of which were two or three small orange trees which were in shade throughout the day. These trees contained some living white flies, whereas other trees immediately surrounding but exposed to the sunshine contained none. Moreover, it can be stated that at no place in India did the writer find living Aleyrodes on small nursery trees except in situations that were well protected by shade.

The most severe and at the same time extensive infestation of the white fly on citrus in India occurred on a large hedge at Lahore, and this was utilized in the writer's breeding and collecting work. A part of this hedge was protected by a cloth awning and this protected portion was infested on all parts. (See Pl. VIII.) On the part not covered with awning the white fly occurred in abundance only where the hedge was protected by densely foliated overhanging trees which kept the direct rays of sunlight from the hedge plants throughout the heat of the day. The side of the unprotected hedge exposed to the direct rays of the afternoon sun was entirely free of living white flies, whereas on the lower part of the opposite side, which was in shade except for a very short period in early morning, living flies could be found in considerable numbers.

In the case of large citrus trees the greatest number of living insects was invariably found in those having the densest foliage. A tree in which the foliage was light seldom contained living flies except where protected by the shade of a large overhanging species. Although the white flies appeared to prefer trees of the tangerine variety, they were seldom able to multiply to any extent on these because of the small leaves and the less dense foliage than that of other varieties. In any species of citrus in which living specimens of the white fly occurred the infestation was found almost invariably in the shadiest part of the tree or the interior part near the main branches.

If large leaves grew in this part of the tree their examination was usually certain to reveal living insects provided the latter were to be found on the tree. In fact, after extended experience in the examination of citrus trees in India, examination of the larger leaves near the trunk of a tree was found to be such a conclusive key to infestation that the writer was able in most instances to "size up" the infested leaves before starting the inspection.

The statements previously made show the destructive action of very high temperatures on the citrus white fly. The prolonged hot, dry summer weather of the plains of northern India checks the development of almost all terrestrial forms of insect life. During the months of July and August, 1911, not only was the development of the white fly at a standstill, but this condition was also noticeable with other species of Aleyrodidæ as well as with all Coccidæ observed. Insects on the wing were seldom seen. In fact, this extremely hot, dry period appeared equally effective in checking the activity of insect life as does a prolonged cold period, such as occurs during the winter in central Florida or in the orange-growing parts of southern California.

That vast numbers of insects are destroyed in these regions of greatest heat is at once apparent to the entomologist who has spent a summer in India. In summing up the writer's experiences and observations he is led to the belief that this hot, dry climate of the Indian plains exerts a greater influence in holding the white fly in commercial control than all other factors combined.

The Effect of Humidity on White-fly Development.

It has been stated by Morrill and Back[1] that "while a normal amount of humidity is necessary for emergence of the white fly to occur, it is not so controlling a factor as temperature during ordinary Florida weather." We have found that the above statement will have to be modified if applied to the Punjab of India, and this is not surprising when it is considered that the normal humidity and temperature of these two countries are so essentially different.

Under normal conditions at Orlando, Fla., the relative humidity at any season of the year rises to nearly or quite 100 per cent by 6 to 10 p. m., and remains at this degree of humidity until the following morning. Rain falls throughout the year, but is lightest during the winter months.

In the Punjab it was found that the humidity is comparatively low throughout the year. With the exception of a few light falls of rain in the winter the rainfall during a normal year is confined to the so-called "monsoon period," occurring in June, July, and August

[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.

and averages about 15 inches. Taken as a whole the climate of the Punjab is very comparable with that of portions of the arid southwestern United States.

The writer's observations were confined almost entirely to the year 1911, during which conditions were somewhat abnormal because of the almost total failure of the rains during the monsoon in the plains of northern India. The prevailing extremely high temperature and low humidity throughout the summer (with the exception of two periods of very light rainfall) gave excellent opportunity for observing the effect of high temperature on the development of the white fly, as well as the effect of humidity on its development and emergence. Throughout the period between April and September the humidity continued so low that at no time was foliage noticeably moistened by dew except in a few instances following precipitation. Heavy dews occur during the autumn and winter months, yet they are much less heavy than in Florida.

With these considerations regarding Indian weather in mind, an attempt will be made to specify its effect on the development of the white fly during 1911. It is quite probable that the emergence of the first brood at Lahore took place about the 1st of April. By May 1 it appeared that practically all eggs had hatched, while the insects were in the earlier stages of development. The temperature during the latter half of April averaged about 82° F. Development continued throughout May, and by June 11 the insects were mostly in the thickened pupal condition or approaching maturity. As compared with that of Florida, development thus far had been about normal. The mean temperature from May 1 to June 11 was 93° F. During the period, June 11 to 15, about 2 inches of rain fell, while the humidity, which had averaged about 39 during the preceding six weeks, now rose to an average of 74. This moisture apparently hastened the development of the pupæ. A few of the more advanced individuals changed to adults and emerged about 10 days after the rain. Almost immediately following this period of precipitation the temperature rose, while the humidity returned to normal. This return to previous hot, dry conditions appeared suddenly to check further development, but such pupæ as had already changed to adults began emerging on June 25, 10 days after the last rain. A very light shower of rain fell on June 26 and appeared to bring out all adults ready for emergence. Within four days practically all adult flies had disappeared from the hedge plants.

This hot, dry weather continued throughout July up to August 20. Slight thunderstorms on July 13 and 14 moderated the temperature a few degrees. The very dry, hot atmosphere immediately preceding and following these rains, as well as the sunshine between showers, almost immediately dissipated any marked change of the tempera-

FIG. 1.

FIG. 2.

FIG. 3.

These hedges were found well infested with *Aleyrodes citri*, and were protected from the rays of the sun by cloth coverings. In all three figures is seen the method of covering, and in figures 2 and 3 is shown the construction of a wooden platform alongside the hedge for holding the potted orange trees. These potted plants were placed in this position so as to become infested with the citrus white fly when the brood emerged on the hedge plants. (Original.)

AN ORANGE HEDGE IN THE BOTANICAL GARDEN AT LAHORE, INDIA.

ture and relative humidity. The relative humidity as taken at 8 a. m. throughout the period of high temperatures and low humidity between the middle of June and August 20 averaged 52 per cent. The temperature during the same period ranged between an average maximum of 106° F. and an average minimum of 84° F. The average mean temperature was 95° F. So great was the effect of this hot, dry weather on the pupæ of the white fly that they remained in a practically dormant condition throughout this interval, and many were killed by the penetrating rays of the sun.

Lahore is situated in the plains about 50 to 100 miles from the Himalaya Mountains. Heavy rains falling in the outer ranges during the latter part of August affected the humidity of the surrounding plains. By August 20 the effect of these rains began to be felt at Lahore and was marked by a high rise in humidity over that of the preceding weeks, while the dry atmosphere changed to one of muggy oppressiveness. This humidity was accompanied by a slight lowering of the temperature. This condition continued for several days and on August 25 heavy showers fell. A very thorough examination of the infested plants on August 26 showed that a remarkable change had taken place within the past few days. All living Aleyrodes were active, as noticed by exudations of honeydew, a condition not seen during the preceding several weeks of dry weather. The pupæ were also changing to adults. This humid weather, accompanied by occasional showers, continued and by August 31 the first adult white flies emerged. By September 2 they could be seen in great numbers. The issuance of adult white flies was at its greatest height about September 7 or 8, while by September 13 practically all adults had emerged and eggs had been deposited very freely.

The foregoing observations show that when dealing with high temperatures, such as in the Indian plains, humidity is the great factor regulating emergence of adult Aleyrodes. Low humidity coupled with high temperatures between the middle of June and the middle of August kept the pupæ in a dormant condition. The approach of a humid atmosphere on August 20 and continuing into September effected immediate development of the white fly and rapid emergence followed.

The effect of humidity on other insects was equally apparent. Several species of scale insects (Coccidæ) which had been in a dormant condition throughout the summer commenced development with the approach of the humid period during the last of August. The rapidity of this development in the case of some species was most striking. Trees which had contained a moderate infestation of inactive scales during the summer months now became severely infested within a fortnight following the first rain.

Prospaltella lahorensis, the True Internal Parasite.

It has been stated in another part of this bulletin that the first definite discovery of parasitic action on *Aleyrodes citri* was made at Lahore, India. Also it was here that at a later date living material of the parasite was first seen. While no special attempt was made to work out the life history of this insect, numerous observations taken during the summer of 1911 while preparing material for introduction into Florida furnish some definite information on certain points of value.

Adult parasites could be found at any time between May and November. They were most numerous during the months of May and September. Although found in June, July, and August, they were so scarce that it frequently required several minutes before a single specimen could be located. Moreover, during this time of great heat a large percentage of the parasites died within the host before maturity. As no evidence of hyperparasitism was evident and since this mortality occurred at all stages of parasite development, the writer is inclined to attribute this mortality to the effects of the hot dry climate. Observations would lead us to believe that at no time did parasitism of the fly exceed 1 per cent.

The parasite prefers the larval stages of its host, but when necessary will oviposit in the pupæ. Parasitized larvæ and pupæ develop a much greater thickness than healthy ones. They also soon lose their transparency, becoming opaque, and this renders them easy of detection. By the use of a lens the parasitic larvæ, which are of a whitish cast, can be seen within the white-fly host. On reaching the pupal stage the parasite becomes very dark, almost black, so that at this time parasitized white flies containing pupa cases appear very dark. Having attained maturity the parasite eats a small hole in the dorsum of the host and through this opening emerges into the open air.

Parasitized Aleyrodes are largely confined to the shadiest part of the plant. The parasite is apparently distributed throughout the citrus-growing region of the Indian Empire.

Infesting Young Orange Trees with Aleyrodes citri.

It has been stated under another paragraph that young trees infested with living white flies were necessary for the safe transmission of parasites from India to Florida. Since young trees infested with the white fly were not available in that country, infestation was secured in the following way: A large portion of the infested orange hedge at Lahore had been protected by a heavy canvas awning. (See Pl. VIII.) Under this awning immediately adjacent to the orange hedge, and on the side away from the midday and afternoon sun, was constructed a narrow platform for potted citrus trees. This platform

was of such height that the top of the young trees placed thereon would approximate or slightly exceed the height of the hedge. (See Pl. VIII, figs. 2, 3.)

Potted plants were arranged on this platform immediately preceding the emergence of the brood of the white fly in September. The awning was then so extended as completely to cover the hedge except at the side on which the plants were placed. This procedure not only protected the foliage from the sun but so shaded the hedge that when the white flies became active in the morning and evening they would come in contact with the potted trees, in their flight toward the light, and thus be more likely to oviposit thereon than upon the hedge itself. All fresh and tender foliage was removed from the hedge before emergence of the white fly took place so as to render its foliage less attractive than that of the potted plants. As a result the flies oviposited freely on the young plants and a gross infestation was thereby secured.

The plants were continued in this position after infestation in order to afford natural conditions for the action of parasites. About the time white-fly eggs commenced to hatch, parasites could be seen running about the young plants, and later it was found that the percentage of parasitism on the young trees was equally as great as had been seen on the infested hedge at any period during the observations.

It was now the middle of October and, believing that all conditions at that time were most opportune for success in carrying through the parasite to America in good condition, the writer commenced boxing the plants on October 18 preparatory to shipment.

Cases Used in Transporting Parasites.

When tender plants are shipped long distances, as from one country to another, a specially made crate called a Wardian case has been used with marked success. These cases much resemble miniature greenhouses, being constructed of heavy wood throughout with the exception of the top, which is made of glass. The cases are perfectly tight except for two small holes at the top, which afford a slight exchange of air with the outside. Plants contained in these cases go great distances without watering. The writer's attention was called to this case by Mr. C. L. Marlatt, assistant chief of this bureau, and by Mr. David Fairchild, in charge of plant introductions in the Bureau of Plant Industry of this department. Request for one of these cases was made to the Government Botanical Garden, Calcutta, and in due time a sample case was constructed and shipped to Lahore. These Wardian cases are used for seedling plants, and consequently are low-topped. It was found that in order to utilize this type of case for our insect-infested plants it would be necessary to make a number of alterations. This was done and the completed case as used for transporting

our material to this country is seen in Plate IX. The base measurement of the cases was approximately 2½ by 3½ feet, while the height varied from 4 to 5 feet. Three large holes were made in both ends of the cases toward the top so as to allow a free exchange of air. These holes were covered with fine brass gauze to prevent the escape of insects. Two small doors were made in each case to be used when watering the plants. These doors were kept open in good weather during the voyage and a specially made fine wire-gauze screen placed in the opening. The glass portion of the case was divided into small sections, six on either side. Thick glass was deep set in the heavy frames so as to reduce to a minimum the possibility of breakage en route.

A rack of half-inch boards rested on the bottom of the case, thus keeping the plant jars from coming in direct contact with the bottom. This helped to minimize the effect of sudden jolts as well as to allow seepage of excess water when the plants were watered. Several auger holes were bored in the bottom of each case. The earthenware jars containing trees were tightly packed with a mixture of the fiber from palm trees and sphagnum moss. Strips of boards were tacked over the tops of the jars to keep them in place. The cases were made in sections held together by screws. They could be easily taken apart and reassembled when needed.

Cryptognatha flavescens,[1] the Predatory Enemy of the Citrus White Fly.

During the autumn of 1910 a small reddish-colored lady-beetle was found destroying the white fly at Saharanpur, India, and two shipments of this species were made at that time to America. All insects were dead on their arrival.

When the writer was carrying on an inspection of citrus trees infested by Aleyrodes, immediately following his return to Lahore in May, 1911, his attention was soon directed to a very few larvæ of this coccinellid busily destroying the white fly. By May 9 the larvæ had become fairly numerous on parts of the infested hedge about which work was centered. Very few adults were seen at this time. During the last ten days of May adults had become numerous, while larvæ were seldom seen, which would indicate that the latter had reached maturity. Careful observations were made June 11 to 14 and the discovery was made that not only had all larvæ disappeared, but the adults as well with the possible exception of an occasional straggler and these too disappeared during the latter part of the month. No Coccinellidæ were seen during July, August, and September, but on October 5 one adult and a few young larvæ were found on young

[1] This insect is mentioned in Indian Insects, by H. Maxwell-Lefroy, under the name *Clanis soror*, as attacking *Aleyrodes* sp. on castor (*Ricinus* sp.).

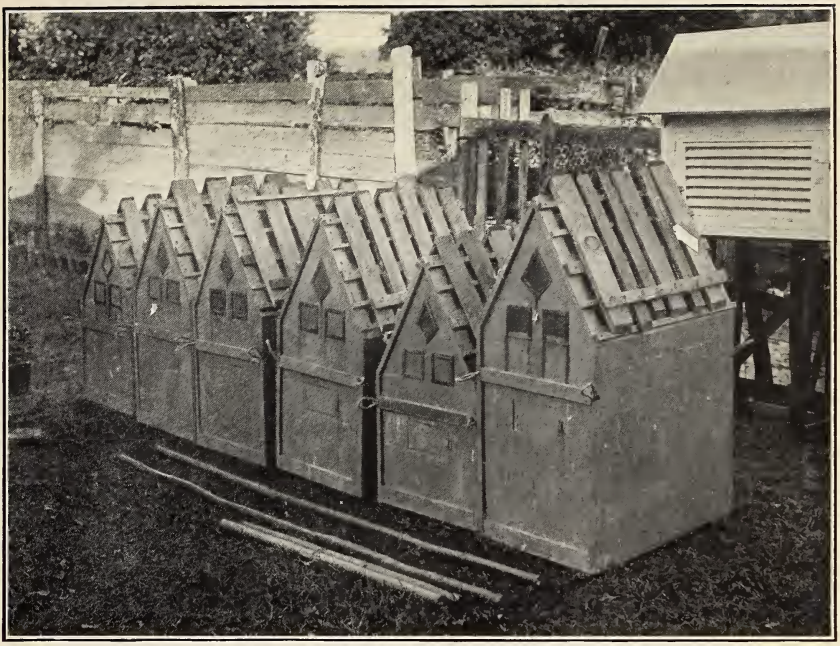


FIG. 1.—THE SIX WARDIAN CASES CONTAINING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY AS THEY ARRIVED AT THE LABORATORY AT ORLANDO, FLA., AFTER THEIR LONG TRIP FROM INDIA. (ORIGINAL.)

FIG. 2.—A WARDIAN CASE WITH THE TOP REMOVED.

This top is tightly fitted on the glass case by means of screws. The elbowed funnel was used in watering the orange trees through the small door at the end. (Original.)

FIG. 1.—THE SIX WARDIAN CASES CONTAINING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY LEAVING LAHORE AT THE BEGINNING OF THEIR LONG JOURNEY TO THE UNITED STATES. (ORIGINAL.)

FIG. 2.—NATIVE HINDUSTANI WHO RENDERED ASSISTANCE TO THE WRITER IN COLLECTING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY. (ORIGINAL.)

orange trees infested with larvæ of the white fly. By October 13 the coccinellid larvæ were in large number and a week later adults had become numerous.

This coccinellid feeds upon the eggs and larvæ of the white fly. A few cases have been noted in which pupæ were attacked. They do splendid work when the proper food is in abundance. The most extreme instance of efficient performance by this lady-beetle was observed on some young potted orange trees severely infested with the white fly in the larval condition. About thirty of these trees were grouped closely together in the shade of a large overhanging tree in the Lahore Botanical Garden in order to secure infestation with parasites. Within a period of 10 days these trees had become inhabited by so many lady-beetle larvæ that the white flies were largely destroyed and the trees were rendered useless for the writer's purpose. This insect has been collected by the writer in the Eastern United Provinces and the Punjab.

Preparation of Beneficial Insects for Shipment.

The coming of the rains during the latter part of August, which resulted in the emergence of the fall brood of the citrus white fly and subsequent infestation of the young potted trees, marked the beginning of a period of steady progress toward successful accomplishment of our endeavors in India. Closely following the hatching of the first white-fly eggs numerous specimens of *Prospaltella lahorensis* could be seen walking around on the leaves of the infested young trees. By the middle of October it was evident that many aleyrodid larvæ had been parasitized. Fortunately large numbers of the coccinellid *Cryptognatha flavescens* had appeared simultaneously with the internal parasite.

Believing it to be the ideal time for preparing the shipment, five cases were packed on October 18 with aleyrodid-infested trees. Each of the cases contained between 10 and 20 trees. Three cases were filled with material parasitized by Prospaltella, while each of the other two cases contained about 150 specimens of the lady-beetle Cryptognatha. The lady-beetles were in both the larval and adult stages.

Transporting the Natural Enemies of the Citrus White Fly from India to the United States.

On October 20, 1911, the five cases of natural enemies of the white fly, together with a sixth case, which contained several valuable varieties of citrus fruit trees native to that country, were placed aboard a train at Lahore and started on their long journey to America. (Plate X.) At Bombay the shipment was placed aboard a vessel bound for Europe. As there are no through steamers between Bombay and New York, it was necessary to transship to other vessels

at Port Said and Naples. Careful prearrangements enabled good connections to be made at both of these ports, so that little delay was experienced throughout the voyage. New York was reached on November 28, exactly one month out from Bombay.

The writer accompanied the shipment and gave it his personal attention throughout the long voyage. The cases were kept on deck except for the last three days out of New York when cold and stormy weather necessitated their being placed below.

CONDITION OF THE NATURAL ENEMIES ON ARRIVAL AT ORLANDO, FLA.

The cases were shipped from New York to Florida by express, arriving at Orlando on December 2, when they were immediately taken to the Government laboratory. An examination of the contents was at once instituted. The ultimate result was the recovery of 28 active and healthy lady-beetles (*Cryptognatha flavescens*) and 8 adult *Prospaltella lahorensis*. A large number of living Prospaltella in both the adult and pupal states were left in the cases.

This condition of the shipment was all that could be desired. A sufficient number of both the predatory enemy and the true internal parasite had arrived in a living condition for breeding purposes. Thus it seemed to the writer that his mission had been successfully terminated.

CONDITIONS AT ORLANDO, FLA., WHEN THE NATURAL ENEMIES ARRIVED.

The writer's return in December was unfortunate but unavoidable. White flies in Florida at this time are in a practically dormant pupal state and continue in this condition during the winter months. Although the winter weather in central Florida causes such tender insects as the white fly to remain inactive, the more resistant species, such as the Coccinellidæ, are not completely driven into winter quarters, but continue to be more or less active during many of the warmest days.

Mr. R. Wooldridge, an agent of this bureau then stationed at Orlando, had on hand a large number of young orange trees infested with the white fly for use in feeding the natural enemies. All these insects, however, were in the pupal stage and then not suitable as food for either of the two introductions, which attack only the younger stages of the white fly.

LOSS OF THE NATURAL ENEMIES.

Without any experience to act upon, it was not easy to determine the best method of carrying these parasitic and predaceous enemies through the winter. In view of the writer's acquaintance with the

conditions in India and from the fact, as he had there determined, that both the parasitic and predaceous enemies of the white fly pass through considerable periods of hibernation, both in the winter season and in the dry season, it seemed to him that the best chance of success was to allow the imported material to go through the winter in a normal condition of hibernation. The alternative was artificially to force, throughout the winter, active breeding of these imported insects and of the white flies as hosts.

With the exception of a small number of the more active specimens of the lady-beetle enemy of the white fly, an attempt was made to carry the imported insects through the winter in a state of hibernation, with the unfortunate result that none of the parasites or of the lady-beetle enemy of the white fly survived.

The small number of more active ladybird beetles referred to were removed from the Wardian cases in which they had been imported and taken into the laboratory and placed on young trees infested with white flies in the dormant, pupal stage. The white fly in this stage was not well suited to them as food, which is by preference the egg and early larval stages, and by the 1st of January all but two of the beetles taken into the laboratory had perished. About the middle of January eggs were obtained from white flies reared in the warm room and the two remaining beetles were removed to a small potted seedling orange tree stocked with such eggs. The feeding of these beetles on the eggs was voracious and they remained alive through the winter but as they were apparently of the same sex they died without reproducing.

The loss of the parasites and the ladybird enemies of the white fly is very regrettable. Possibly such loss can be avoided, if another importation is made at the same period, by adopting the method of keeping the insect enemies and host insects in active breeding throughout the winter in a suitably constructed and well-stocked greenhouse. Possibly an even better chance of success will come from importations so timed as to arrive in early summer.

THE POSSIBLE EFFICIENCY OF THESE NATURAL ENEMIES IF ESTABLISHED IN FLORIDA.

Considering the comparative weather conditions of Florida and the parts of India infested with the white fly, the writer sees no reason why *Prospaltella lahorensis* and *Cryptognatha flavescens* could not be successfully established in this country.

It has already been stated that neither of the two natural enemies of the white fly exerts any great effect in controlling the white fly in India. The great natural enemy of the white fly in that country is the excessive heat, and this very element which limits the injuriousness of the white fly is, in the writer's opinion, largely the one that keeps

down the natural enemies of this pest as well. Probably the adults of Prospaltella never emerge from the majority of parasitized larvæ and pupæ of the fly, and this because of their destruction by heat previous to the time for their exit. This same extreme weather which limits the white fly to two distinct broods has both a direct and an indirect effect on the lady-beetle. Since this insect destroys only the younger stages of the white fly, the heat has an indirect effect by limiting the breeding of the pest to two distinct broods, so that there is only a very short time in the spring and in the fall during which food for the coccinellid is available. The direct effect is that the extreme heat produces a deterrent influence on the lady-beetle's activity.

It may be well to state what could be expected of these natural enemies if established in Florida. At the very maximum of possible efficiency the writer believes they would fall far short of commercially controlling the white fly. In fact, it is very doubtful if its commercial control by natural enemies alone is possible. Granting that this high degree of control could not be expected, the writer's observations and experience lead him to believe that the introduction of these natural enemies, especially the lady-beetle, is likely to result in sufficiently beneficial results to be well worth the while. Especially would this be so when these natural enemies were working in connection with the different fungous enemies of the fly now found in Florida.

The elimination in this country of the checks to the development of these natural enemies, which exist in India, would assuredly have a beneficial effect. Whereas in India the white fly can be found on citrus trees only in small quantities and is limited to two distinct broods, the situation is entirely changed in Florida in that there are several broods in a single year. The presence of an adequate food supply throughout a large part of the year, in a climate in which the most extreme day of summer is sufficiently mild to allow their free activity, would seem to present such a favorable situation that these natural enemies of the white fly must needs accomplish excellent results after becoming thoroughly established.

DESIRABILITY OF CONTINUING THE ATTEMPT TO INTRODUCE THESE TWO NATURAL ENEMIES.

It has been pointed out in the preceding discussion that conditions in Florida appear favorable to splendid results from the establishment of these natural enemies, especially the lady-beetle (*Cryptognatha flavescens*). As previous experience has shown how best to cope with the situation in order to carry it through to a successful termination, the present would seem an inopportune time to terminate endeavors in parasite introduction. We have detailed information of localities in which to find the natural enemies, the proper

season of the year for their collection, the most successful methods to be employed, manner of shipment, and all other factors regulating the procedure. A greenhouse could be prepared in Florida, so that there would be breeding Aleyrodes on hand at all times of the year.

As an outline of a second attempt at introducing the natural enemies of the white fly, the writer would make the following suggestions on the basis of his past experience: The work should be carried along on a more extensive scale than previously and with the object of continuity should the first attempt fail. Two men should be sent abroad, to arrive in India by March 1. This would give time for adequate preparations before the appearance of the first brood of the white fly in April. Several cases such as were used by the writer in his expedition should be filled with aleyrodid-infested trees and transported to India. This would insure a supply of Aleyrodes as well as citrus trees should any difficulty be experienced in an attempt to secure either on arrival in India. Having collected a supply of natural enemies, one of the two men could return with the same to America while the second man remained in India carrying out preparations for securing material from the second brood of the white fly. Then, if the first shipment should prove a failure, no time would be lost in the second attempt. Should the first shipment come through successfully, as soon as this was definitely known the agent in India could be informed. He could then proceed to the great citrus-fruit-growing regions of southern China and endeavor to find other natural enemies of the white fly in this little-known region, in which it is quite possible the Aleyrodes originated. The writer is very strongly of the opinion that in China there should be other natural enemies not found in India.

FOOD PLANTS OF THE CITRUS WHITE FLY.

The citrus white fly has attained its great economic importance in the United States because of its injurious action to citrus fruit trees. Specific consideration of this matter has been given on pages 11–12 of this bulletin. It has been stated by Drs. Morrill and Back that in the Gulf States oranges of the tangerine group are preferred hosts over other varieties of citrus. This same preference was observed by the writer in India. Similarly, other varieties of oranges are preferred to grapefruit, which was always found highly infested or else free of this insect. Lemons and limes appeared to stand intermediate in point of infestation between oranges and grapefruit. Some varieties of limes were quite as much preferred hosts as oranges. Although living specimens of the white fly were usually found on the larger leaves of infested plants, because of the greater protection from the sun, it is a point of much interest that grapefruit trees were much less severely infested than the orange, although in general their larger leaves produced a more dense shade than those of the former.

The citrus white fly has other host plants than the varieties of citrus, and below is given a list of its definitely known food plants as taken from Bulletin 92 of this bureau, page 29:

Definitely known food plants of the citrus white fly (Aleyrodes citri).

CLASS I. PREFERRED.

Introduced:

1. Citrus (all species cultivated in America).
2. China tree (*Melia azedarach*).
3. Umbrella China tree (*Melia azedarach umbraculifera*).
4. Cape jessamine (*Gardenia jasminoides*).
5. Privets (*Ligustrum* spp.).
6. Japan persimmon (*Diospyros kaki*).
7. Lilac (*Syringa* sp.).
8. Coffee (*Coffea arabica*).

Native:

9. Prickly ash (*Xanthoxylum clava-herculis*).
10. Wild persimmon (*Diospyros virginiana*).

CLASS II. OCCASIONALLY INFESTED.

Introduced:

11. Allamanda (*Allamanda neriifolia*).
12. Cultivated pear (*Pyrus* spp.).
13. Banana shrub (*Magnolia fuscatum*).
14. Pomegranate (*Punica granatum*).

Native:

15. Smilax (*Smilax* sp.).
16. Cherry laurel (*Prunus laurocerasus*).
17. Wild olive or devil wood (*Osmanthus americanus*).
18. Viburnum (*Viburnum nudum.*)
19. Green ash (*Fraxinus lanceolata*).

The bulletin just referred to goes on to say that in addition to those of the foregoing list there are several species reported as food plants of the white fly which, although probably true food plants, can not consistently be included in the recognized list until the observations have been repeated and the infesting species positively identified.

Authorities on the white-fly situation in this country appear agreed that the economic control of this insect necessitates proper attention to different food plants. It can then be seen that in case a citrus orchard was so treated that the fly was eradicated therefrom, the presence of other species of infested food plants in the immediate neighborhood which might escape treatment would furnish a direct source for its reinfestation. Knowledge of the different kinds of food plants would readily enable the horticulturist to determine before treatment whether or not his sole efforts could be devoted to his orchard trees.

As the white fly is an introduced pest it has also been conceded that knowledge of the different preferred food plants might assist materially in the discovery of the original host plant as well as indirectly the original home of the insect. Practically all investigators

of the white-fly situation in the Gulf States agree that the China and umbrella trees (*Melia* sp. and var.) are the greatest breeders of the white fly of all known food plants including the citrus. In speaking of the umbrella China tree Morrill and Back state:

> First this insect shows in one respect a greater degree of adaptation to this food plant than to citrus plants, as shown by the very low rate of mortality in immature stages. The second important point is that adult citrus white flies are so strongly attracted by growing leaves of umbrella trees that under certain conditions with umbrella and citrus trees growing side by side more adults collect on three or four umbrella leaves than are present on entire citrus trees of medium size.

From the preference shown in the white-fly region of this country for the different China trees some entomologists have even ventured to state that they believed these trees to be the original host plants. It is known that China trees are native to Asia, and that certain species occur wild in India. The writer found these trees common in northern India, and many were examined. In no instance, however, was the white fly found on China trees in that country, although in some cases the foliage of these trees came in contact with aleyrodid-infested orange plants.

Jasminum sambac.

Some of the most common bushes throughout India belong to the genus Jasminum, and of these probably *Jasminum sambac* is the most common species. This plant is used for ornamental purposes in yards and gardens, but is of especial importance through cultivation for its very fragrant flowers, which are used in making scented oil as well as in connection with various religious performances of certain native sects. Patches of one-fourth, one-half, or even an acre in size are common throughout northern India, and the writer has seen the plant in every other part of this country in which he has traveled. The special point of interest is that these bushes are invariably infested with the white fly, and usually more or less severely. The writer has seen patches of this plant in which almost every leaf of each plant contained some living white flies. Bushes were sometimes found to be very black with sooty mold, a condition never seen in citrus trees. Not infrequently has the writer examined as many as a score of orange trees with the result of finding living material on only one or two, whereas every Jasminum bush in the immediate vicinity would contain much living material. In the Central Provinces no white flies were seen on citrus trees, yet in numerous instances Jasminum bushes planted between the trees, in some cases even touching their trunks, contained many active insects.

In conclusion, it might be stated that in all localities in which Jasminum bushes were examined, which included northern and central India, these were found infested with *Aleyrodes citri*, and

frequently somewhat severely. The white fly was found on citrus trees throughout this region, with the exception of the Central Provinces and the Bombay Presidency; in these places it was seen only on Jasminum. Probably the majority of citrus trees examined were entirely free of the white fly, and where this insect was present it was entirely under control, barring two or three exceptions. On the Jasminum, however, it was seldom that living material was not present, and frequently infestation was more or less severe.

The Jasminum is a low, spreading bush with very dense foliage, which remains on the plant throughout the year. The broods of the white fly on this species are not distinct as on the citrus plants, which was shown by the presence of adult white flies on Jasminum at several different times between the months of May and October.

Enough has already been stated to show the preference, in many instances in India, of the white fly for the Jasminum rather than for citrus plants. The following additional evidence is in itself conclusive: During May, while adult flies were emerging in large numbers on a Jasminum bush, a number of small seedling orange trees of very tender foliage were placed immediately about the plant, so that the leaves of the orange trees were in contact with those of the Jasminum. Very few flies settled on these orange trees, while large numbers would be present on leaves of the Jasminum within a few inches of the former. Even if the bush was so disturbed that the flies in their flight would settle on the orange trees they would ultimately desert these in order to go back to the original food plant.

In addition to citrus plants and Jasminum the only other host of *Aleyrodes citri* seen in India was a large-leaved vine—*Hiptage mandalobata*. The citrus white fly appears to be less parasitized on these two hosts than on citrus trees.

PROBABLE NATIVE HOME OF ALEYRODES CITRI.

Authorities on citrus fruit trees are generally agreed that the native home of this group of plants is southeastern Asia. The writer's observations in the Orient support this conclusion in all respects. By far the most common variety of citrus fruit in the Oriental region is the tangerine (Mandarin) orange, including other forms so closely allied as evidently to belong to the same group. Tangerines are found everywhere that citrus plants can be grown. The writer has seen them throughout the Indian Empire, where they form the bulk of the orange crop, in Ceylon, Java, and the Philippines. In China they are extensively grown and are found also in southern Japan. That oranges are not native to but have been introduced from the mainland into the surrounding islands is

very evident from observation of their present condition in the latter places, even if we had no more conclusive evidence. Oranges do very poorly owing to the great humidity of these tropical islands. The trees for the most part are stunted, while the crop of fruit is invariably very light, of small size, and usually ripens without the greenish skin changing to an orange color, as it does in more temperate climates. In short, orange trees in the eastern Tropics appear to be struggling under conditions so ill-suited to their best development, whereas in a semitropical climate they flourish with great prolificness, that it is very evident that they originated in the latter regions.

In India proper oranges do not occur wild. Although grown in all parts of this large country their distribution has resulted after introduction. In the Khasia Hills of Central Assam oranges occur in a half wild state intermingled with the other trees of the forest. They are grown in the extreme northeast of Assam where the Indian Empire is adjacent to southern China. Information was received from an engineer in the Indian service who had traveled extensively along the eastern border of the Empire to the effect that he had seen oranges growing wild in the forests of the North Shan States of Upper Burma. This latter region, which is contiguous with orange districts of China, is only about 300 miles east of that part of Assam in which the writer saw oranges in a half wild state. Oranges are known to occur in southern China, Siam, and Indo-China. From this knowledge, coupled with the writer's own observations, it can be seen that oranges are grown in a more or less scattered condition throughout southern Asia, where climate allows. Eliminating the varieties found in various botanical gardens and on the estates of wealthy natives, and the limited amount of commercial production, the remaining trees in all countries are for the most part seedlings of the tangerine group. In the valleys along the southern slopes of the Himalayas as well as in the Khasia Hills of Assam this is almost exclusively the case. When it is considered that oranges in the eastern part of India are almost exclusively tangerine seedlings, and that these are found growing about most of the native houses as well as being in a half wild state in a part of this region—a condition that does not occur anywhere to the westward—we feel safe in concluding that oranges were first introduced into India through Assam and thence have spread throughout the rest of the Empire. The western region was later affected by varieties introduced from Europe, for it is in this part of India, including the northwest, that budded varieties of citrus trees predominate.

The writer has seen the white fly on citrus trees in the Khasia Hills of Assam, in the lower parts of the Himalayas in Sikkim, and

westward throughout northwestern and north-central India. He has also seen this insect at Macau, in southern China, while in the collection of this bureau in Washington is material on orange leaves collected at Canton, southern China. These records are sufficient to lead to the belief that the white fly occurs on citrus plants throughout southern Asia. If citrus is the original food plant of this insect (but we have no conclusive evidence that it is) it would then appear quite probable that its original home was in that part of southeastern Asia in which citrus plants originated and that it followed the distribution of the citrus through other parts of that continent.

In India the white fly prefers Jasminum as a host plant over citrus trees. On this plant the insect was of much greater occurrence and capable of withstanding climatic conditions better than on any other host. Viewing the problem entirely from the standpoint as seen by the writer in India, it would appear that Jasminum was the original host rather than citrus. The most commonly cultivated species of Jasminum, called *sambac,* is considered a native of India, but other allied species are native to China. Various species are cultivated throughout subtropical Asia. Hence it is quite probable that the white fly infests this plant in China as well as in India.

The lightest infestation of the white fly occurs in the eastern part of India while the most severe infestation is in the northwest. Considering climatic conditions one would expect the contrary, as the weather of Assam is of greater humidity and less extreme temperature than the upper country. Trees in the Khasia Hills at between 1,000 and 1,500 feet elevation and surrounded by forest trees so as to be abundantly protected by shade were so lightly infested that only an occasional insect could be found and most of these were parasitized. Although the infestation in the northwest was so light that the insect was in a satisfactory condition of control it could be generally stated to be much more severe than in eastern India. This condition, together with the fact that the only known reports of injury from the white fly received in the Indian Museum came from the northwest during the early nineties, leads the writer to believe that this insect is of recent introduction into that region.

After all has been said and we know that citrus and Jasminum are the present preferred food plants of *Aleyrodes citri* in southern Asia, nobody is able to state definitely that either is the original host, even though indications would tend to point that way. Nevertheless, it is sufficiently certain as to be considered a fact that the citrus white fly is a native of the semitropical part of continental Asia, and the strongest indications point toward the Indo-Chinese region as its original home.

APPENDIX A.

CITRUS FRUITS IN INDIA.

The climate of India is suitable to the production of citrus fruits from the lower altitudes of the outer Himalayas southward throughout the peninsula. Although many places throughout this vast region are splendidly adapted to citrus fruit growing, the acreage at present in commercial production is so limited as to fall far short of meeting even the home demands. Pomelos and limes are of general distribution and lemons are grown to a limited extent, but it is the orange alone that attains commercial prominence.

The locations of supply most widely known and largely depended upon are the Khasia Hills of Assam (Pl. XI, fig. 1), the Nagpur district in the Central Provinces (Pl. XI, fig. 2), Poona in the Bombay Presidency, and Gujranwala in the Punjab. The Khasia Hills supply much of the fruit used in the Calcutta and Assam markets. The chief center of orange cultivation in these hills is a narrow strip of country bordering the south and west sides, which extends from the plains up to an altitude of not more than 1,500 feet. The Khasia orange gardens are seldom composed exclusively of orange trees, but have them scattered through the forests with other trees, especially the areca palm, from which the betel nut is derived. To the American, trees of such a character in a half-wild state would scarcely be looked upon in the light of commercial production, but in India they form the chief source of supply for the entire eastern part of the Empire. These oranges are all seedlings and of the shape and flavor of tangerines. They are inferior to American-grown tangerines in both size and flavor.

The Nagpur orange is the most famous orange in India. The supposed excellence of this fruit is so widespread that it has almost developed into a tradition that in no place else can such excellent oranges be grown as in this limited region. The writer is of the opinion that this popular conception is largely a fallacy. Orange growing at Nagpur has been known for many years, and doubtless at present is carried on there with more care than in almost any other place in India. The fruit almost exclusively produced in this region is a very loose-jacketed tangerine, somewhat above the average size of this orange. It is produced on budded trees, in the selection of which some care was originally used. When it is considered that the bulk of the oranges grown in India are from seedling tangerine trees, many of which develop into unusual monstrosities through lack of selection, it is easily understood that the competition of a large, loose-jacketed fruit, with such an irregular assortment, would quickly place it in a prominent position. The orange production about Nagpur is much less than would be expected, as the total supply is probably taken from far below 1,000 acres.

This so-called Nagpur orange can be grown in other sections with equal success and is the orange largely produced about Poona in the Bombay Presidency. In fact, the writer was informed on good authority that the so-called Nagpur orange purchased in the Bombay markets does not come from the Nagpur region, but rather from Poona.

At Gujranwala, in the Punjab, the Malta orange is the principal kind produced. The trees are budded and in general are in a well-kept and healthy condition.

The normal time for gathering the fruit is November and December. In the more southern and warmer parts of the country the fruit is ready for market in November, but in the Punjab, as well as the outer Himalayan tracts, it is not picked until December. About Nagpur and Poona in the central Provinces two crops of fruit are gathered—one in November, the other in April. The first crop comes at the normal period of fruiting, while the second is produced artificially by the well-known method of removing the dirt from a part of the root system, the result of which is such a shock to the tree than an extra period of blossoming is brought about. The roots are exposed during the dry season in late spring. Irrigation is not practiced throughout this period, which is of about a month's duration. After exposure of the roots for about one month they are heavily irrigated, and in a short time after this treatment the blossoms are said to appear. The maturity of this crop in April, which is an off-season period for oranges, results in the fruit commanding a high price.

In the plains the fruit is carried loose in ox carts to the market place or bazaar, while in the mountainous districts it is first carried in baskets by native bearers (Pl. XII, fig. 1) to the nearest bazaar (Pl. XII, fig. 2), from which it is shipped to the railroad either by country boat or ox cart. The price paid for fruit is variable. One grower at Nagpur stated that he received 1½ to 3 rupees (50 cents to $1) per hundred for fruit at his orchard, while in one of the obscure bazaars in the outer Himalayas, upon which the writer happened, the natives brought oranges in baskets on their backs from points many miles distant to sell at the rate of about 600 for 1 rupee (32 cents).

Citrus trees in India are never pruned. Fertilization is practically unknown except for a few instances in which a little manure is added. The best orange groves are plowed frequently in order to keep down the weeds. Irrigation is almost universally practiced in those places where much fruit is produced. Many horticulturists irrigate every week or 10 days during the warm, dry season. The common system in practice is by means of a single furrow along the base of each row of trees, so that the trees rise directly out of the furrow. Hence the bases of the trees are always standing in water while the irrigation is taking place.

FIG. 1.—ORANGE PRODUCTION IN THE KHASIA HILLS OF ASSAM.

In many of the Khasia gardens the orange trees are intermingled with trees of the forest. Long bamboo ladders are necessary for reaching the fruit. (Original.)

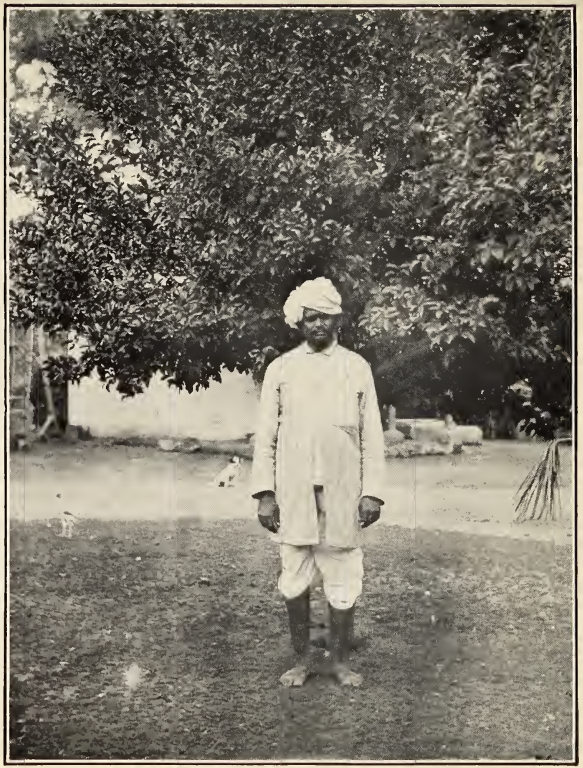


FIG. 2.—A NATIVE ORANGE GROWER, OWNER OF THE LARGEST GROVES IN THE FAMOUS NAGPUR DISTRICT OF CENTRAL INDIA. (ORIGINAL.)

ORANGE PRODUCTION IN INDIA.

FIG. 1.—NATIVES IN THE PROVINCE OF SIKKIM CARRYING ORANGES IN BASKETS TO THE BAZAAR, WHERE THEY ARE PURCHASED BY BUYERS FROM THE LARGE CITIES.

At this bazaar the oranges were brought through the mountains by native carriers from distances as great as 10 to 15 miles and sold at the rate of 600 for 1 rupee (32 cents). (Original.)

FIG. 2.—AN ORANGE BAZAAR IN THE OUTER HIMALAYAS.

Oranges are here purchased from the natives and transported to the railroad in oxcarts. (Original.)

TRANSPORTING ORANGES TO MARKET IN THE OUTER HIMALAYAS.

APPENDIX B.

INSECT PESTS OF CITRUS TREES SEEN BY THE WRITER DURING HIS INVESTIGATIONS IN VARIOUS FOREIGN COUNTRIES.

SPAIN.

Chrysomphalus dictiospermi (Morg.).
Parlatoria zizyphus (Lucas).
Pseudococcus citri (Risso).
Lepidosaphes beckii (Newm.).
Lepidosaphes gloveri (Packard).
Aspidiotus hederæ (Vall.).
Saissetia oleæ (Bern.).
Coccus hesperidum (L.).

ITALY AND SICILY.

Chrysomphalus dictiospermi (Morg.).
Parlatoria zizyphus (Lucas).
Lepidosaphes beckii (Newm.).
Pseudococcus citri (Risso).
Aspidiotus hederæ (Vall.).
Saissetia oleæ (Bern.).
Coccus hesperidum (L.).

INDIA.

Chrysomphalus aurantii (Mask.).
Chrysomphalus aonidum (L.).
Erium sp.
Monophlebus dalbergiæ Green.
Pseudococcus citri (Risso).
Aspidiotus lataniæ Sign.
Lepidosaphes beckii (Newm.).
Lepidosaphes lasianthi (Green).
Coccus hesperidum (L.).
Fiorinia theæ Green.
Vinsonia stellifera (Westw.).
Aleyrodes citri R. & H.
Aleyrodes, 3 species (undetermined).
Papilio demoleus L.
Phyllocnistis citrella Stainton.
Bud moth (*Agonopteryx* sp.).
Borer.

The determination of almost all the Coccidæ included in these lists has been made by Mr. E. R. Sasscer, of this bureau. The scale insects have been arranged in order of economic importance in so far as was possible from the observations of the author and information available. Without doubt the most serious insect pest in India is *Phyllocnistis citrella,* a leaf-mining lepidopteron. It is especially destructive to young nursery stock. While the infestation of individual trees by other of the Indian citrus pests is occasionally somewhat severe, these infestations are not so general as to be of commercial importance.

APPENDIX C.

OBSERVATIONS ON COCCIDÆ AND THEIR NATURAL ENEMIES IN SPAIN, ITALY, SICILY, AND INDIA.

Most species of Coccidæ and Aleyrodidæ seen during the writer's travels in tropical and semitropical regions were parasitized to a greater or less extent. Some species appeared to be attacked by a single natural enemy while other species were affected by several. It might be safely stated that the combination of climatic conditions with natural enemies keeps all scale and aleyrodid enemies of citrus trees in India under commercial control except for occasional sporadic outbreaks. In Spain, Italy, and Sicily also climate and natural enemies have proved of great efficiency against numerous citrus-tree scale pests.

The following specific treatment will be largely confined to pests observed during the writer's travels abroad, which are of economic importance in the United States.

Spain, Italy, and Sicily.

Chrysomphalus dictiospermi is the most destructive pest of citrus trees in these three countries. According to Prof. Silvestri, the eminent Italian entomologist, this species was first noticed in Italy and Sicily in 1909. Fortunately the infestations of this insect are of a localized nature in these countries. In Spain it is widely distributed and undoubtedly was present here many years before its appearance in Italy. The species is attacked by numerous natural enemies, both parasites and predators, in all three European countries.

Parlatoria zizyphus, the pest which ranks in point of injuriousness next to *Ch. dictiospermi* in these three Mediterranean countries, does not occur in citrus groves in the United States. It can thus be seen that the citrus groves of this country are free of the two pests most injurious to the same plants in southern Europe. *Chrysomphalus dictiospermi* has been reported in greenhouses from most parts of the United States, but no record of the definite establishment of *Parlatoria zizyphus* is at present known.

Lepidosaphes beckii, *Saissetia oleæ*, and *Pseudococcus citri*, namely, the purple and black scales of California and the citrus mealy bug, which are very serious pests in our own country, produce very little serious injury in the Mediterranean region. It should be of the greatest interest to the citrus fruit growers of California, who spend so many hundreds of thousands of dollars annually in combating these pests, to know that in the chief citrus-fruit producing countries of southern Europe these same pests, though present, are for the most part under natural control so that artificial effort is seldom necessary for their subjugation. To quote from a communication respecting this subject received from Prof. Silvestri:

> The other species of citrus pests (which include the purple and black scales and the mealy bug) produce here and there some injury, but not continually nor so great that the cultivator has any interest in attempting to control them with insecticides. Only occasionally does an outbreak occur of such serious nature as to require artificial means of control.

Lepidosaphes beckii, the purple scale, was observed in Spain but only in such slight infestations, so far as the writer's observations extended, that it may be said to be under commercial control. Mr. L. Salas, the agricultural engineer of the Province of Malaga, informed the writer that the purple scale was once very severe in parts of that Province, but for some unknown reason had suddenly disappeared in recent years. A similar report was heard from another authority in that Province. In Italy and Sicily the purple scale is

generally distributed, but is serious only by sporadic outbreaks as stated by Prof. Silvestri. This species is attacked by Coccinellidæ of the genera Chilocorus and Exochomus. Silvestri states that some Acari (mites) eat the eggs.

Saissetia oleæ, the black scale, is another pest generally distributed through Spain, Italy, and Sicily, but is in such perfect control in these countries as to be of no special economic importance. Wherever it was seen the writer always found *Scutellista cyanea* Motsch., the internal parasite, attacking it. Prof. Silvestri states that the black scale is attacked in Italy and Sicily by *Scutellista cyanea*, *Coccophagus flavoscutellum* Ashm., *Erastria scitula* Ramb., and Coccinellidæ of the genera Chilocorus and Exochomus.

Pseudococcus citri is the species of insect which is of the greatest interest to many citrus fruit growers in this country. The purple and black scales can be easily controlled by artificial means, especially fumigation, but these methods have thus far proven unsuccessful against the citrus mealy bug. In certain parts of southern California *Pseudococcus citri* is a very serious pest. However, in Italy and Sicily as well as to a large extent in Spain it is in such perfect control as to be of little commercial importance. Only one grove in Spain was seen by the writer to be at all severely infested by this pest, and in this many larvæ and pupæ of a dipterous parasite were observed among the masses of mealy bugs. A second species of parasitic insect, probably a dipteron, was observed in another part of that country.

The mealy bug was seen in many groves in Sicily, but always to such a limited extent as to do no injury to the trees. Practically every mass of insects examined showed evidence of parasitism. A dipterous species appeared most common. Prof. Silvestri informed the writer that *Pseudococcus citri* is attacked in that country by two species of Chalcididæ, by two to three species of Neuroptera, by a species of Leucopis, and by Coccinellidæ of the genera Chilocorus and Exochomus.

Since the citrus mealy bug is so well under control in Italy and Sicily as well as to a great extent in Spain, it is at once evident that this region should prove a fertile field for study in an endeavor to overcome the mealy-bug pest on citrus trees in America. That natural enemies take a leading part in this natural control of the citrus mealy bug in southern Europe must be admitted by anyone who has carefully examined the prevailing conditions there. The writer is of the opinion that a thorough investigation of the citrus districts of the Mediterranean by a competent entomologist, including extended shipments to this country of the different available natural enemies of such citrus pests as Pseudoçoccus, Saissetia, and Lepidosaphes, especially the former, would prove a very profitable economic investment for the citrus fruit growers of America.

India.

The main portion of this bulletin is devoted to a treatment of two natural enemies of *Aleyrodes citri*, so no further mention of these species is necessary. *Chrysomphalus aurantii*, the red scale so injurious to citrus fruits in California, occurs throughout India, but in such slight quantities as to produce little injury. Sometimes individual trees in shady situations are severely infested, but such instances are very infrequent. The scale on such trees is invariably found to be heavily parasitized by a species of the hymenopterous genus Aphelinus. *Chilocorus nigritus* Fab., an oriental coccinellid, also attacks this scale. *Pseudococcus citri*, the citrus mealy bug, was very seldom seen in India and in those instances observed was under perfect control. It is quite probable that the species is attacked by natural enemies.

APPENDIX D.

COCCINELLIDÆ INTRODUCED FROM INDIA.

Several species of ladybirds of economic value were included with the shipments of the natural enemies of the white fly. All have failed to develop with the exception of two species, *Chilocorus nigritus* Fab., which preys on various species of Coccidæ, and *Chilomenes sexmaculatus* Fab., which preys upon aphides.

Chilocorus nigritus did admirable work against *Chrysomphalus aurantii* in certain parts of India and was introduced in the hope that it might prove of economic value if established in this country. It is at present being successfully reared in California and Florida.

Chilomenes sexmaculatus feeds on various species of Aphididæ. It is a rapid breeder. One female in captivity has deposited over a thousand eggs. Vast numbers of this species have been reared and liberated in both California and Florida.

APPENDIX E.

FUMIGATION OF CITRUS TREES IN SPAIN.

When the writer stopped in Spain in 1910, while en route to India, no fumigation had ever been practiced. *Chrysomphalus dictiospermi* and *Parlatoria zizyphus* were such serious pests as to have become a menace to profitable orange production in certain parts of the country. The growers affected were eager for some method to control these insects even as were the orchardists of California when the cottony cushion scale was such a pest before *Novius cardinalis* had been introduced.

The writer spent the month of August, 1910, in Spain in an attempt to demonstrate the efficiency of fumigation with hydrocyanic-acid

gas against these insects. Compte de Montornes, the Royal Commissioner of Agriculture from Valencia, and Leopoldo Salas, Agricultural Engineer of Malaga, had been appointed by the Minister of Agriculture to supervise such demonstration experiments as were necessary. Through the aid of these gentlemen paraphernalia essential for the equipment of a field fumigation crew such as the writer has used in California [1] were acquired so far as was possible. Intelligent men were selected and drilled in the procedure, so that before leaving Spain a crew competent to carry on field fumigation under the direction of the two eminent Spanish authorities had been established. Dosage tables of the character used by the writer in California were introduced into Spain.

The initial procedure of 1910 has developed very rapidly. In a letter recently received from the Compte de Montornes he stated that now there are 10 complete outfits of 30 tents each, as well as several smaller ones in different parts of Spain. Six of these outfits belong to the Government, the remainder to societies and private individuals. The results everywhere were said to be very satisfactory, and as the success of the process is becoming known to the growers it is producing a great demand for more extended operations.

[1] Bul. 90, Part I, Bur. Ent., U. S. Dept. Agr., 1911.

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